THE BRAZILIAN PULP INDUSTRY: PERFORMANCE AND POTENTIAL FOR BIOENERGY GENERATION

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OUTLINE:

- Introduction
- The Brazilian Forest and Pulp Industry
- Energy Matrix
- Opportunities and Challenges
- The pulp mill bio-refinery
  - Approaches
  - Potential in Brazil

Introduction

- Brazilian forest sector:
  - Only 3.5% of GDP
  - Great potential
  - Industry and University R&D well established in forestry
  - Weak R&D in pulp and paper and ligno-cellulosics
  - Great potential for R & D cooperation with foreign institutions

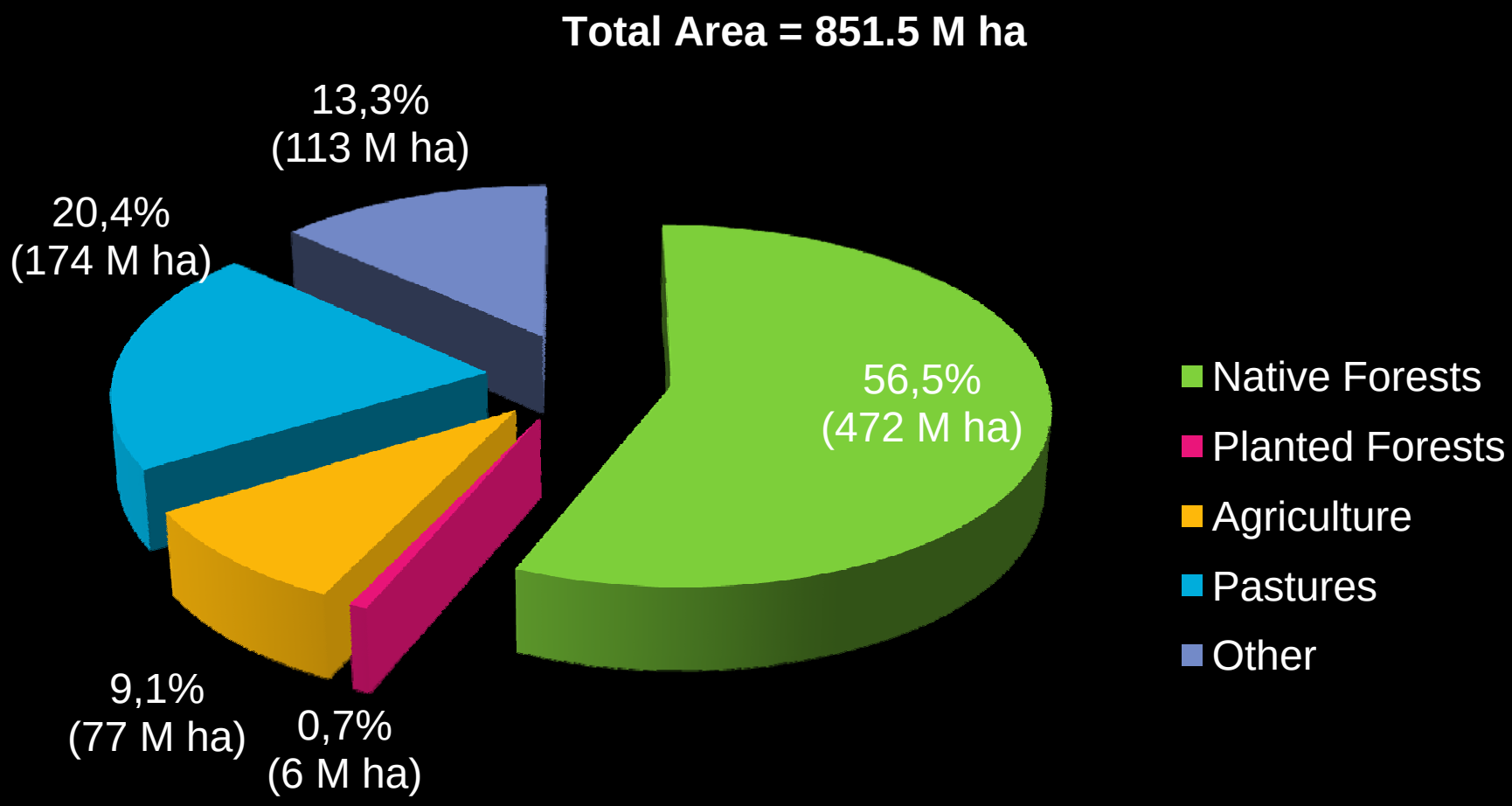
Forest, Pulp and Paper Industry

Territorial Occupation

- **Territorial area: 851 M ha**
- **Forested area: 478 M ha**
- **Protected area: 220 M ha**
- **Natural Forests: 472 M ha**
- **Planted Forests: 6 M ha**
- **Forests *per capta*: 2.56 ha/person**

Source: SBS, 2009.

TERRITORIAL OCCUPATION



Planted Forests: Main wood species

Species	Area, ha	%
Eucalyptus spp.	3,751,867	62.7
Pinus spp.	1,808,336	30.2
Acacia nigra	189,690	3.2
Hevea spp.	85,768	1.4
Paricá	79,159	1.3
Tectona grandis	48,576	0.8
Araucaria spp.	17,500	0.3
Populus spp.	2,800	0.06
Other	1,701	0.04
Total	5,985,397	100

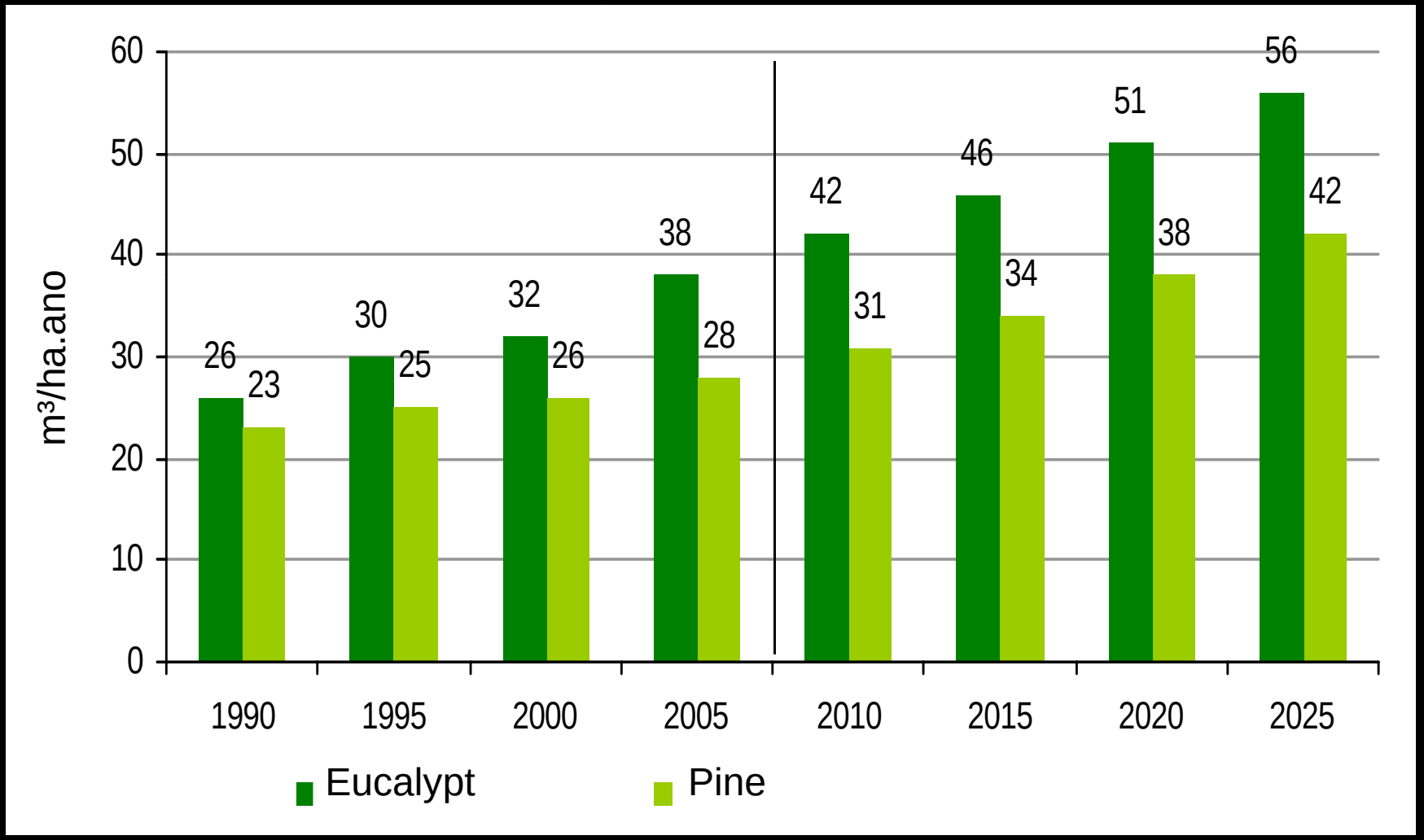
Source: ABRAF, 2009.

Productivity of Planted Forests

Species	$m^3/ha/yr$
Acacia (*Acacia spp*)	15 - 25
Álamo (*Populus deltoides*)	20 - 30
Araucária (*Araucaria angustifolia*)	10 - 25
Bracatinga (*Mimosa scabrela*)	25 - 35
Eucalyptus (*Eucalyptus spp*)	**30 - 40**
Pará-Pará (*Jacaranda copaia*)	30 - 35
Paricá (*Schizolobium amazonicum*)	20 - 30
Pine (*Pinus spp*)	25 - 30
Teak (*Tectona grandis*)	15 - 20

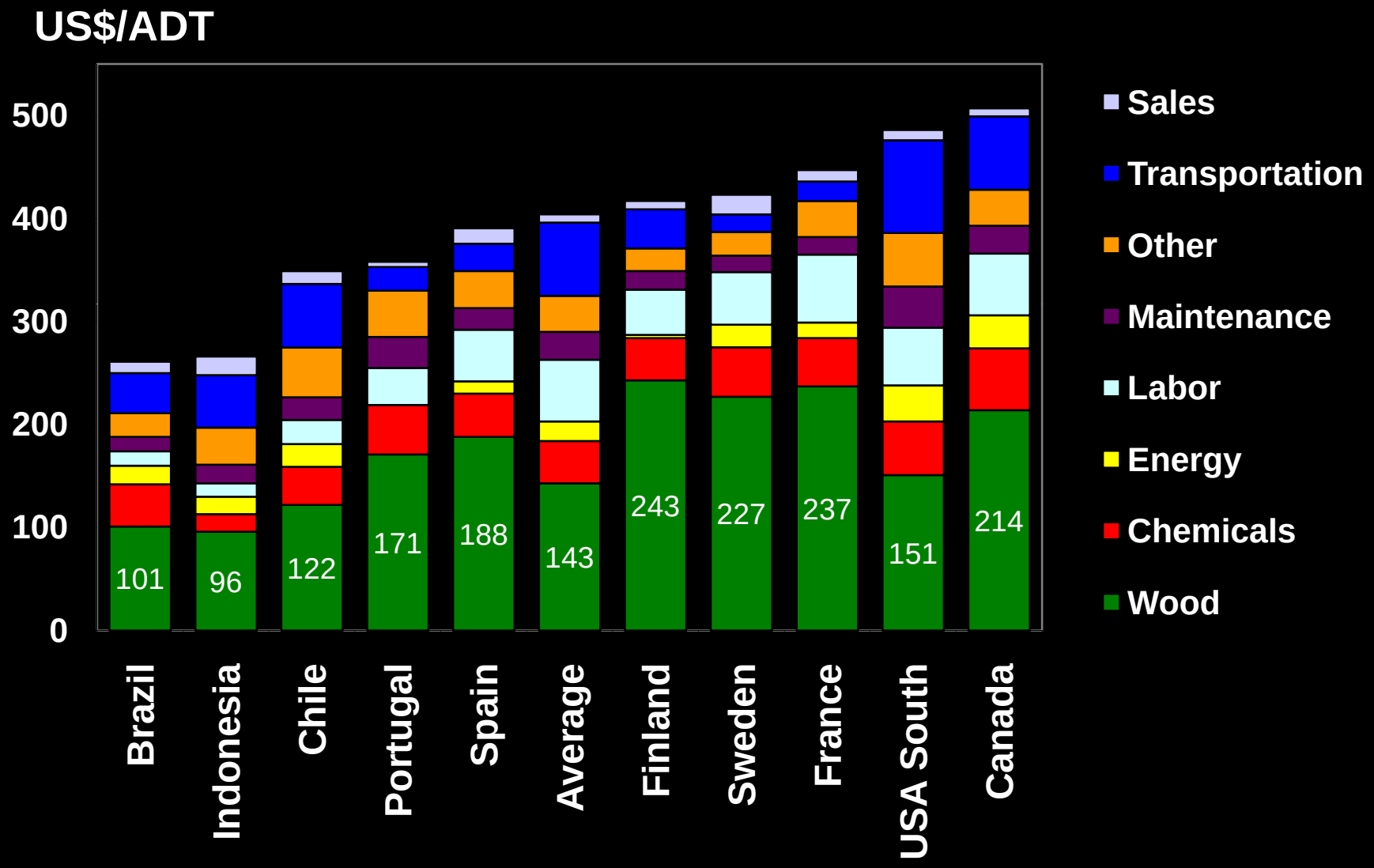
Source: SBS, 2007.

PLANTED FORESTS– PRODUCTIVITY PERSPECTIVES



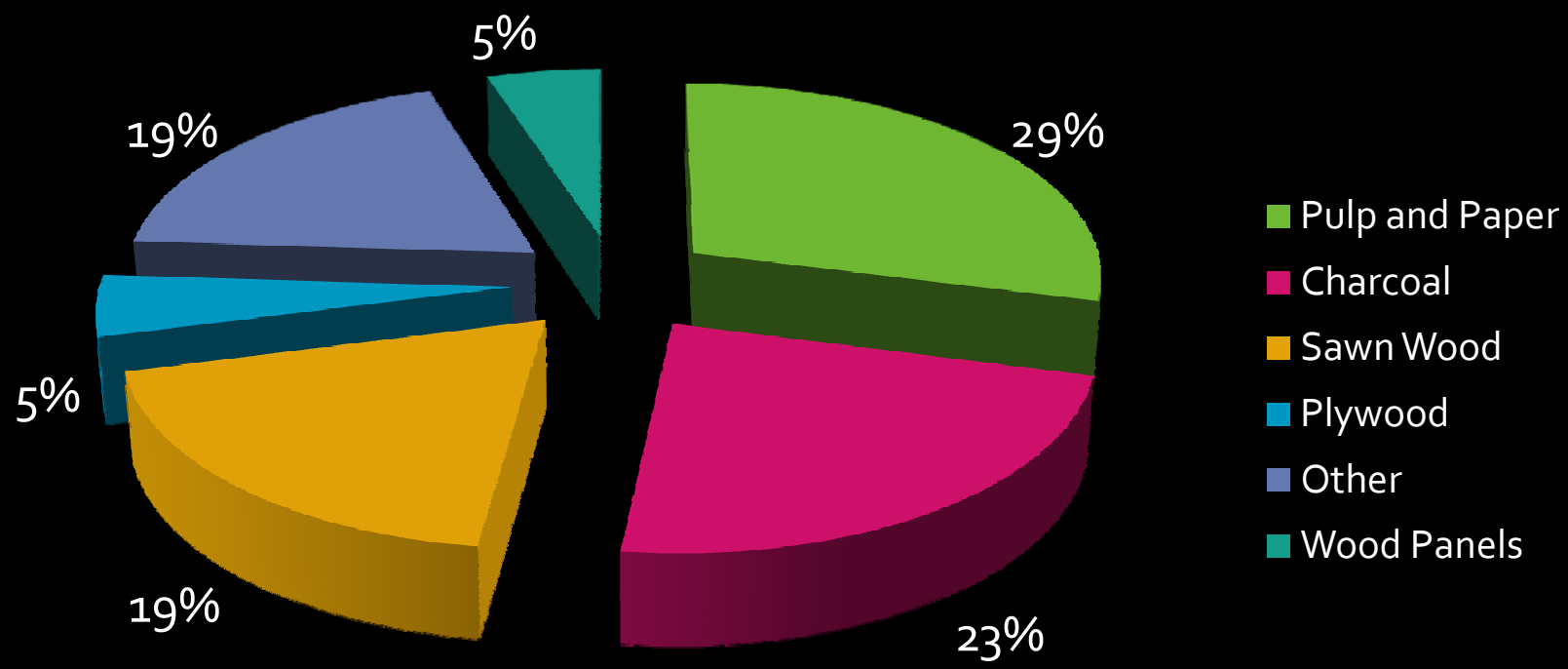
Source: STCP, 2007

Bleached HWD Fiber Production Cost Composition in 2006



Source: Outlook for Market Pulp Demand, Supply, and Prices, HAWKINS WRIGHT LTD, July 2006.

Round wood Consumed in 2007 by Industrial Segment



Source: Abraf, 2008

The Forestry Sector in Numbers

- 3.5% of the Brazilian GDP and 7.3% of the exports,
- 4.2% of the world forest products exports,
- 14.6% of the positive trade balance and 1.4% of total tributes,
- 1 million direct jobs and invested US$13.3 MM in 1998-2007,
- Of the total Brazilian exports, the forest products segment is the fourth largest source of exportations (7.3%), behind food/beverages/tobacco (17%), metal products (12%) and vehicles (10%).

Sources: SBS/Abimci/BNDES, AMC2008.

The Forestry Sector in Numbers

INDUSTRIAL SEGMENT	REVENUES, US$MM
Pulp, paper and board	12.97
Charcoal (steel industry)	12.73
Furniture	6.46
Wood panels	1.87
Mechanically Processed Wood	1.87
Others Non-wood	1.37
Total	37.28

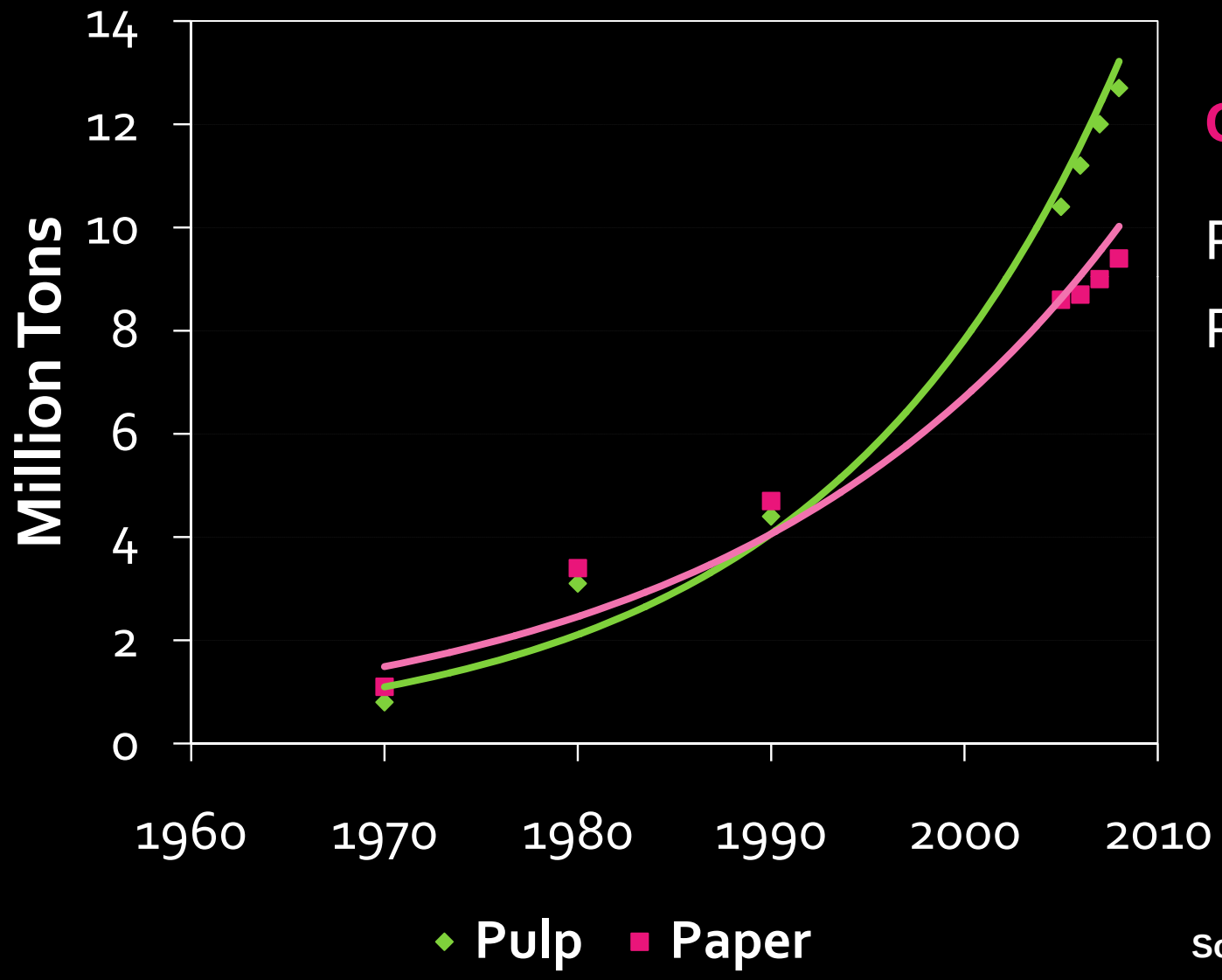
Source: SBS, 2007.

Pulp and Paper in Numbers

- In 2008 Brazil produced 12.7 M tons of pulp,
- Fourth world pulp producer behind USA, China and Canada,
- First producer and exporter of hardwood market pulp,
- **Of the total pulp production:**
  - **83.6% comes from HWD chemical**
  - **12.1% from SWD chemical**
  - **4.3% from HWD/SWD high-yield pulps.**
- Brazil is the twelfth world paper producer with 9 M tons in 2008.

Source: Bracelpa, 2007.

Production Growth



Grow Rates:

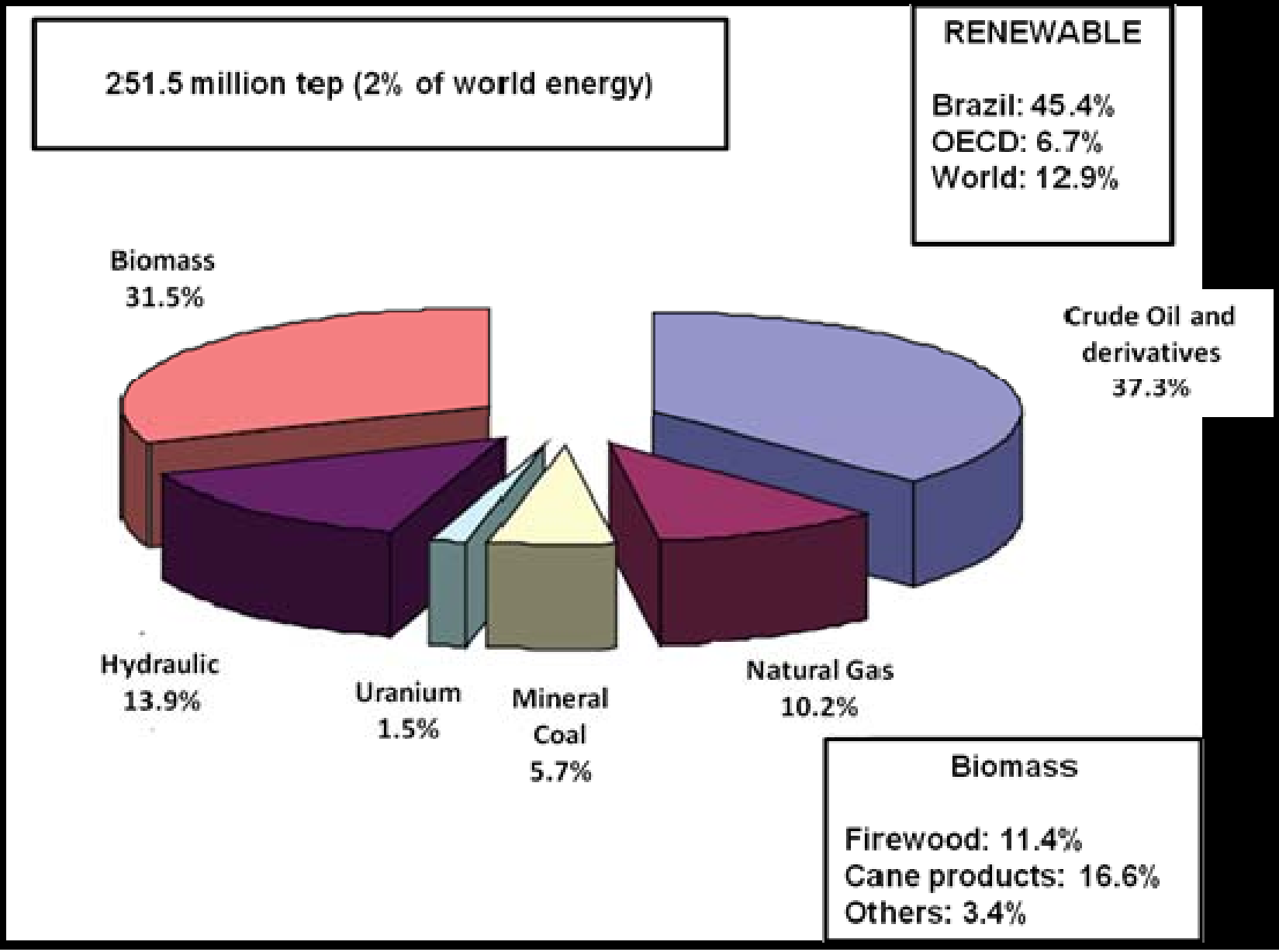
Pulp= 7.5%

Paper = 5.8%

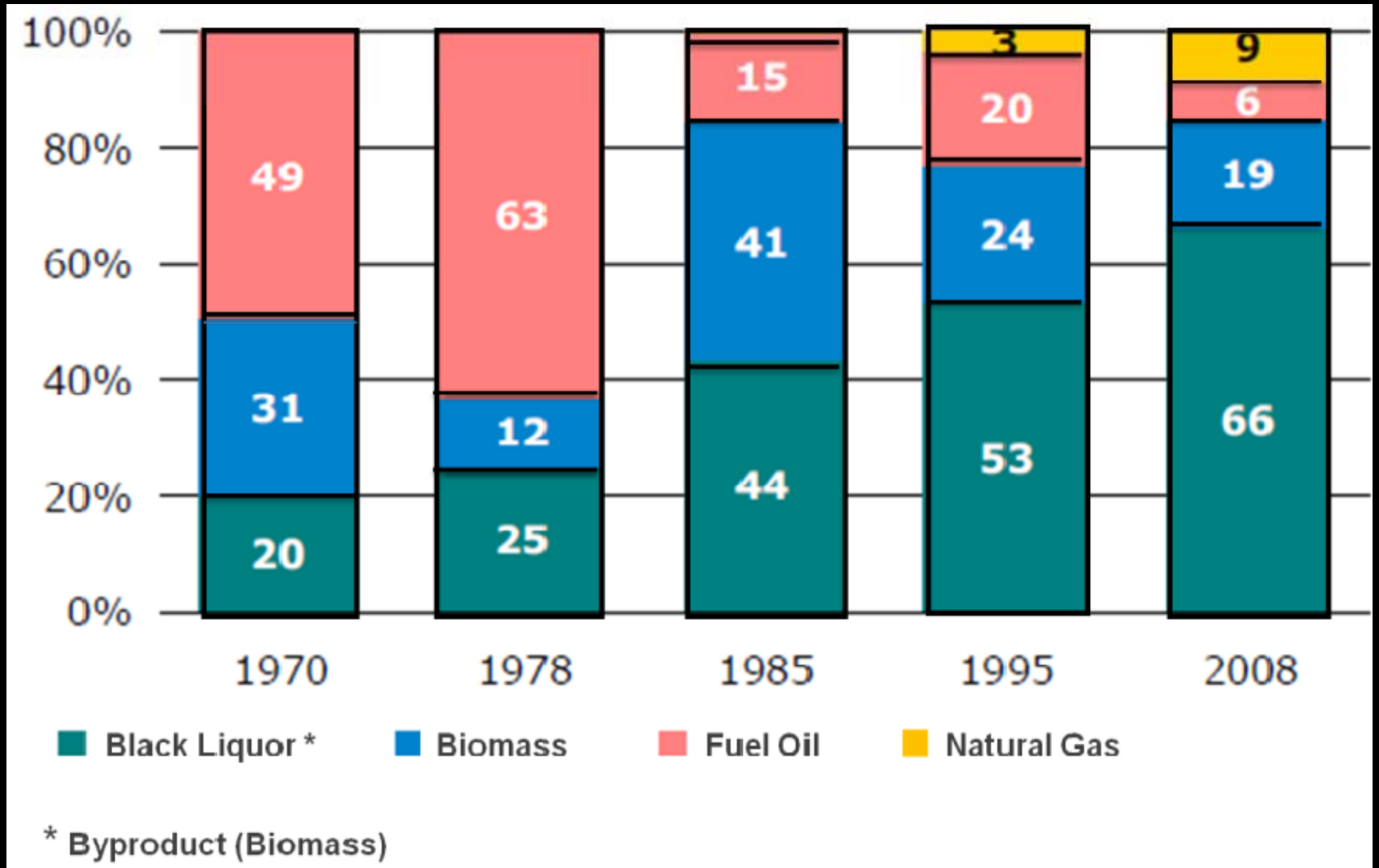
Source: Bracelpa, 2009.

The Energy Matrix in the Pulp and Paper Industry

Brazilian Energy Output in 2008



The Pulp and Paper Industry Energy Matrix



The Energy Balance for Veracel Pulp Mill

ELECTRICAL ENERGY	YEAR 2006	YEAR 2007
Total Generated, kWh/adt	783	846
Energy for Pulp Production, kWh/adt	592	556
Energy Purchased from the Grid	0	0
Energy Sold to the Grid, kWh/adt	191	290 (34%)

Wood consumption for pulp and energy production

Wood	For Pulp Production, solid m^3 w/b	For energy production, solid m^3 w/b	Total, solid m^3 w/b
Eucalyptus spp.	37.367.661	2.467.536	39.835.197
Pinus spp.	7.726.348	1.498.159	9.224.507
Araucaria spp.	18.964	0	18.964
Other	118.202	583.449	701.651
Total	45.231.175 **(~91%)**	4.549.144 **(~9%)**	49.780.319

Specific Goals in Forestry

- Increasing plantation area and productivity
- Improving wood quality for value added products
- Tools for large scale wood quality evaluation
- Improving logistic
- Broadening the forest base (new fast growth species)
- Decreasing harvesting age, maintaining wood quality
- Land use (companies own most of their forests) – more emphasis on outgrowing required
- Capturing more carbon credits

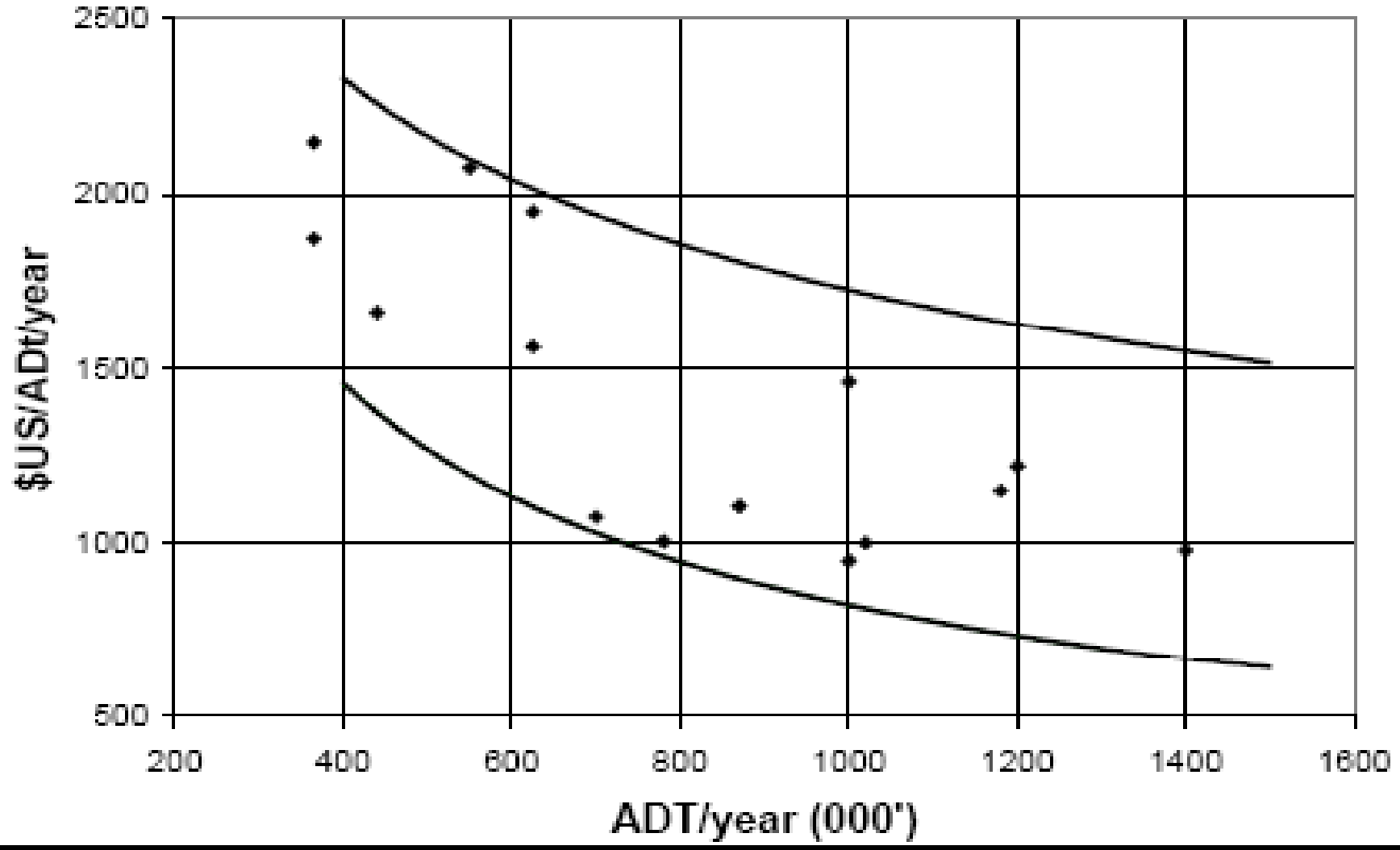
Specific Goals in Pulp and Paper

- Productivity improvements
- Eucalyptus fiber strength improvements and vessel content control
- Eucalyptus fiber drainability and refinability improvements
- Processing of very high density woods
- Lowering chemical usage
- Online controls for improving process uniformity
- Minimizing water and energy consumption
- Minimizing liquid, solid and gaseous discharges

Future Challenges

- Finding new high value added applications for wood fiber (fiber modification)
- Diversifying product line by including energy, chemicals, materials and smart products
- Decreasing capital costs
- Accommodating very large pulp (5000 tpd) and paper (3000 tpd) capacities in single lines
- Moving towards the closed cycle (minimum impact) mills.

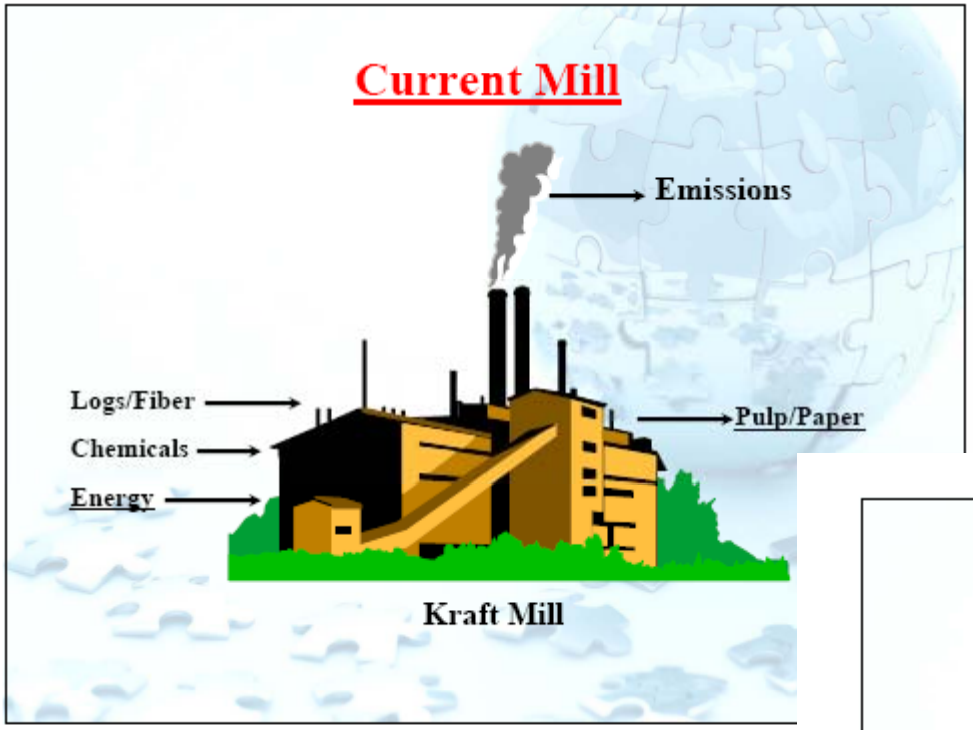
Pulp mill capital cost range

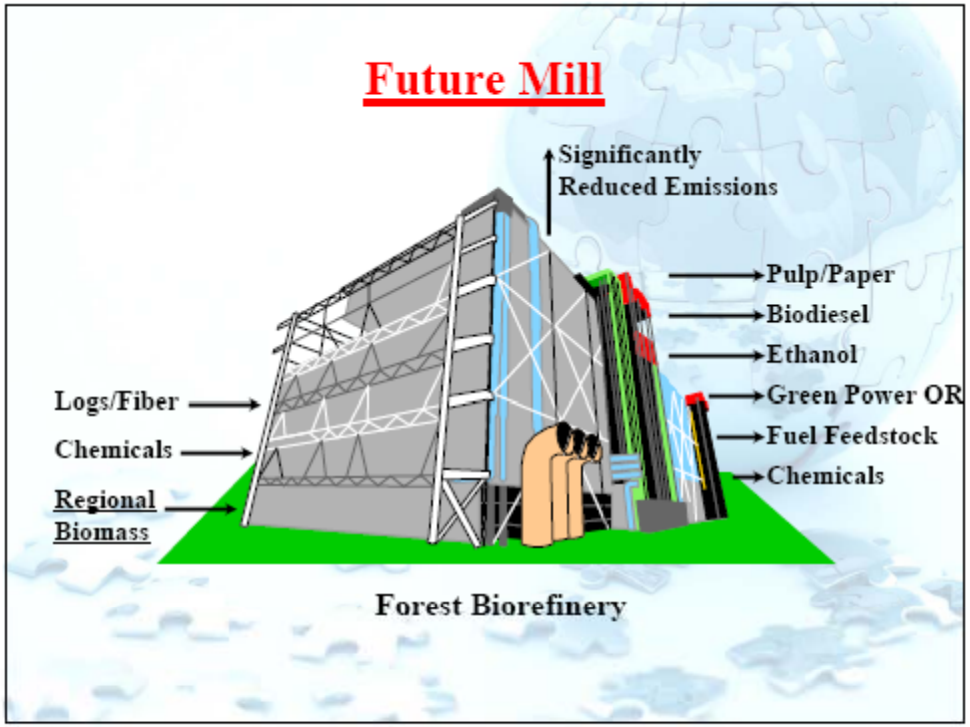


Source: AMEC, 2008

The Pulp Mill Bio-Refinery

What Exactly is a Pulp Mill Bio-refinery?





Ben Thorp et al., Compelling case for integrated Biorefineries, Nordic Wood Biorefinery Conference; Stockholm, March 11-14, 2008.

Important Aspects of Bio-refineries

- Should not compete with food production
- Efficient from a greenhouse gas perspective
- Cost-effective so as to avoid farming and other types of subsidies

Keys to Successful Deployment of pulp mill bio-refineries

- How are bio-refineries synergistic with pulp and paper production, and in what ways are they competitive?
- Specifically, what will be the impact of bio-refineries and biomass powered boilers on biomass supply and pricing for pulp and paper production?
- Bio-refineries have high capital costs and carry significant financial risks. What alliances will be necessary to make bio-refineries a reality?

Why Pulp and Paper Industry?

- Industry owns and manages operation of feedstock harvesting, transportation and storage. Raw material is already being supplied to the mills
- Industry has experience in chemical processing and handling in compliance with related standards and Regulations
- Location of facilities in rural areas can realize important synergies between agricultural and forest based feedstock
- Ethanol production from wood based material uses significantly less fossil fuel than other biomass resources

Wood *vs* agricultural-based feedstocks

- "Do not compete with food uses"
- Can be very productive
- Forests require less-intensive management (fertilizer, irrigation, harvesting, etc.)

Ethanol Production by Crops (some residuals left on the ground to avoid erosion)

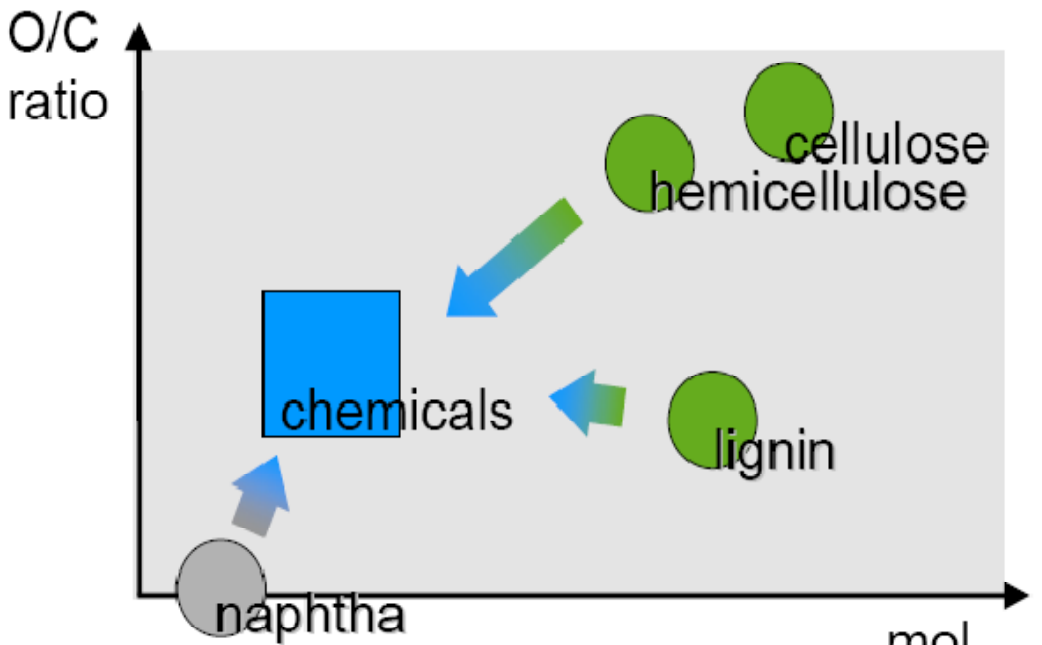
Feedstock	Litre Ethanol per ha/year	Total
Corn + stover	2500 +1200	3700
Wheat + straw	1800 +1100	2900
Sugarcane + bagasse	8300 +4100	12400
Wood - Eucalyptus*	9100	9100

* Considering a MAI of 40 m^3/ha/year, 500 kg/m^3 wood density and 455 L EtOH /ton of wood.

Sune Wannstrom et al., Ethanol from cellulose – integration is a must. Wood Biorefinery Conference; Stockholm, March 11-14, 2008

Chemicals from biomass

- biomass: a mixture of highly functionalised chemicals
- low transport density
- low energy density
- dilute solutions
- solid handling
- fractionation
- defunctionalisation



⇒ **key technologies:**

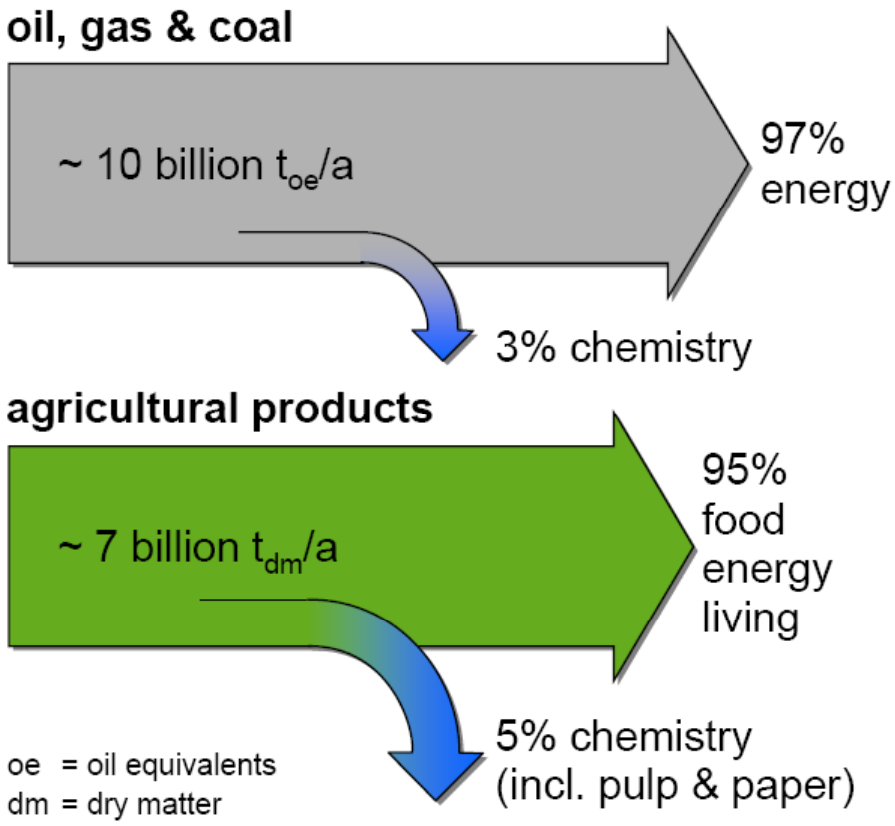
- refinement

- catalysis (chemical & biotechnological)

Tim Balensiefer, From fossil based to forestry based chemicals?Nordic Wood Biorefinery Conference; Stockholm, March 11-14, 2008

Global use of fossil and renewable raw materials

BASF
The Chemical Company



- finite supply of fossil fuels and climate change mitigation will first have an impact on the energy sector
- biomass: potential as raw material and energy source
- energy supply cannot be based on biomass only
- competition with nutrition inadmissible

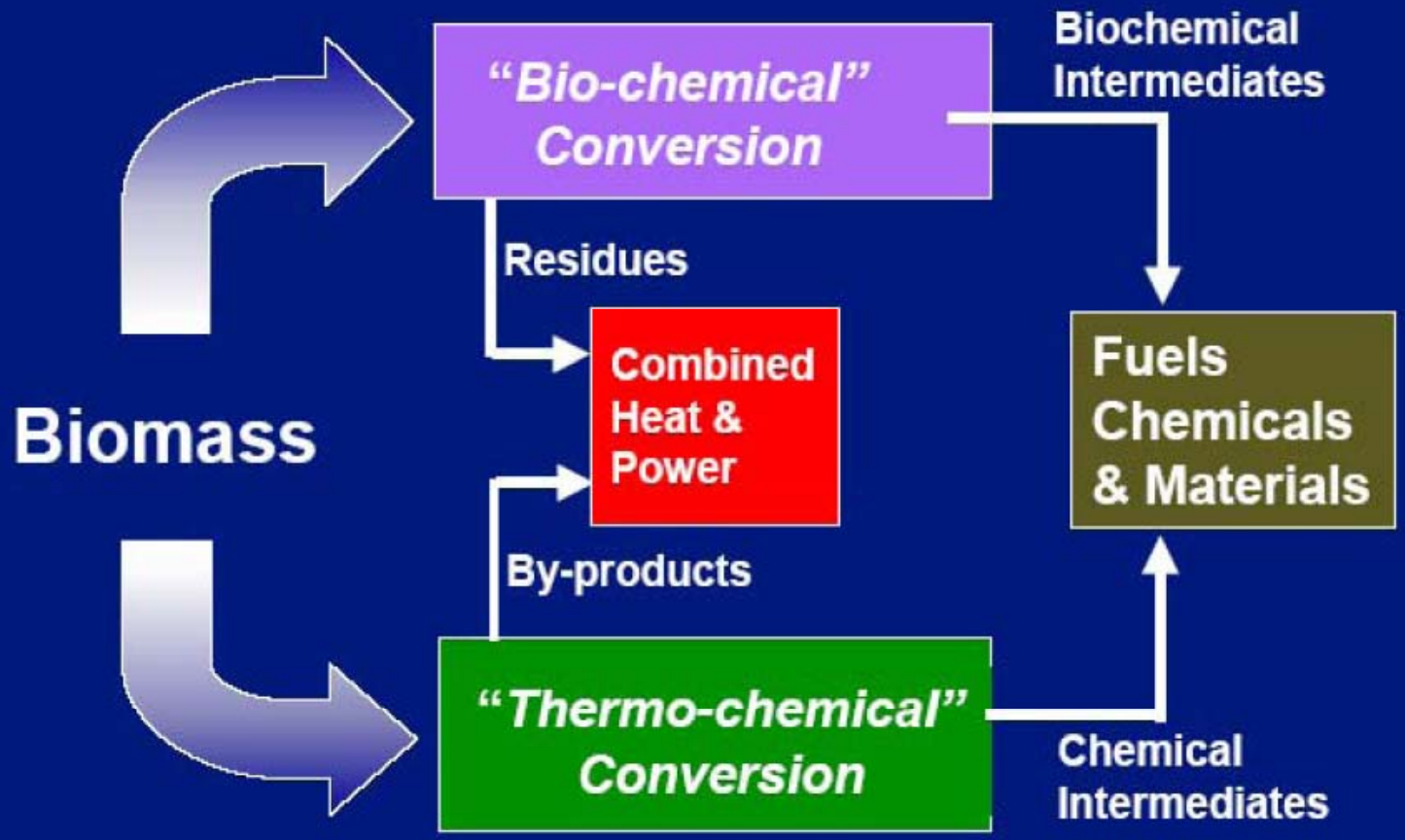
source: IEA, BASF, FAO

Tim Balensiefer, From fossil based to forestry based chemicals?Nordic Wood Biorefinery Conference; Stockholm, March 11-14, 2008

PULP MILL BIO-REFINERY APPROACHES

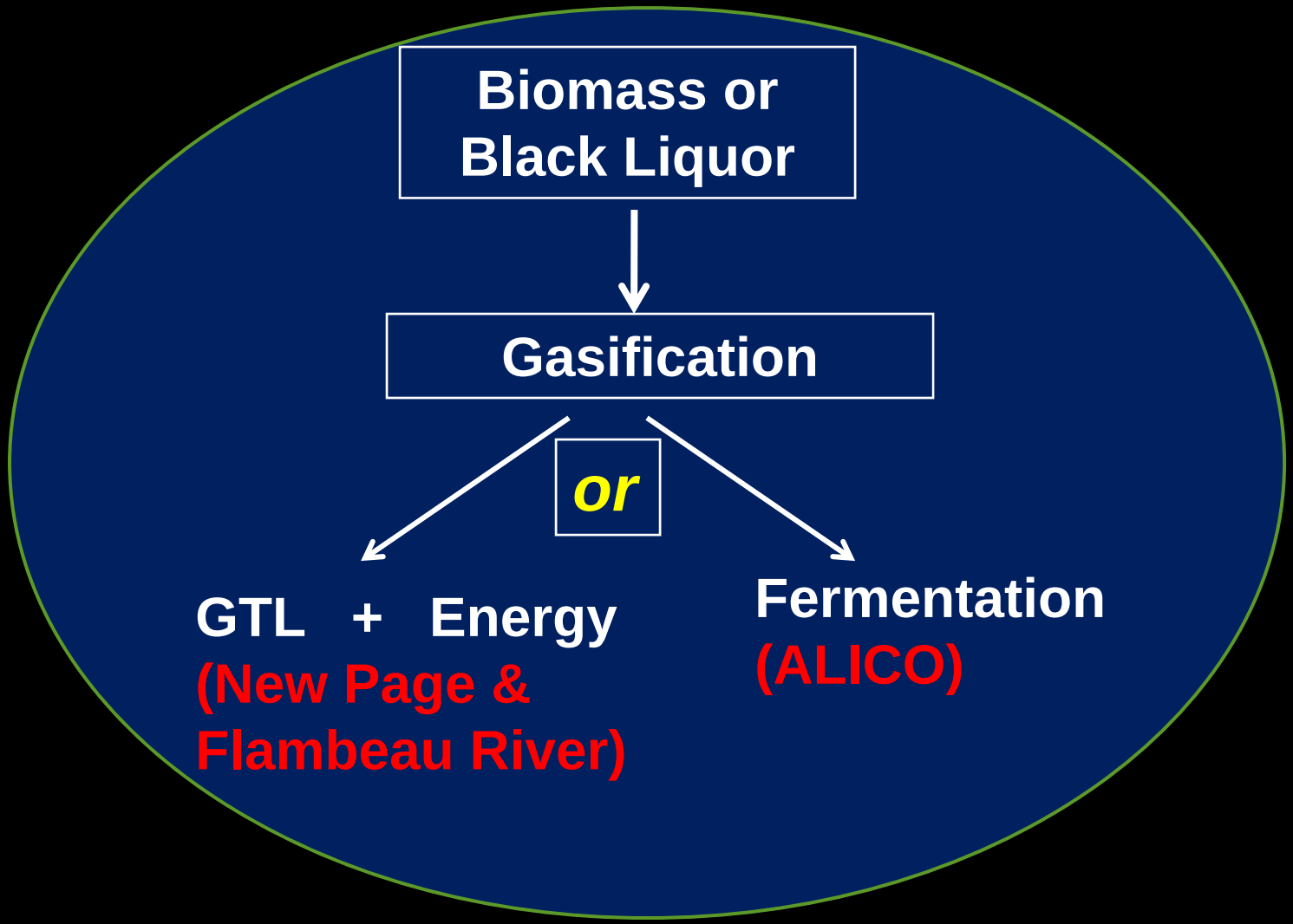
Ben Thorp et al., Compelling case for integrated Biorefineries, Nordic Wood Biorefinery Conference; Stockholm, March 11-14, 2008.

Two Platforms of Biomass Conversion



“pathways for which there is already hardware on the ground or at least proposed commercial facilities”

Thermo-Chemical Conversion



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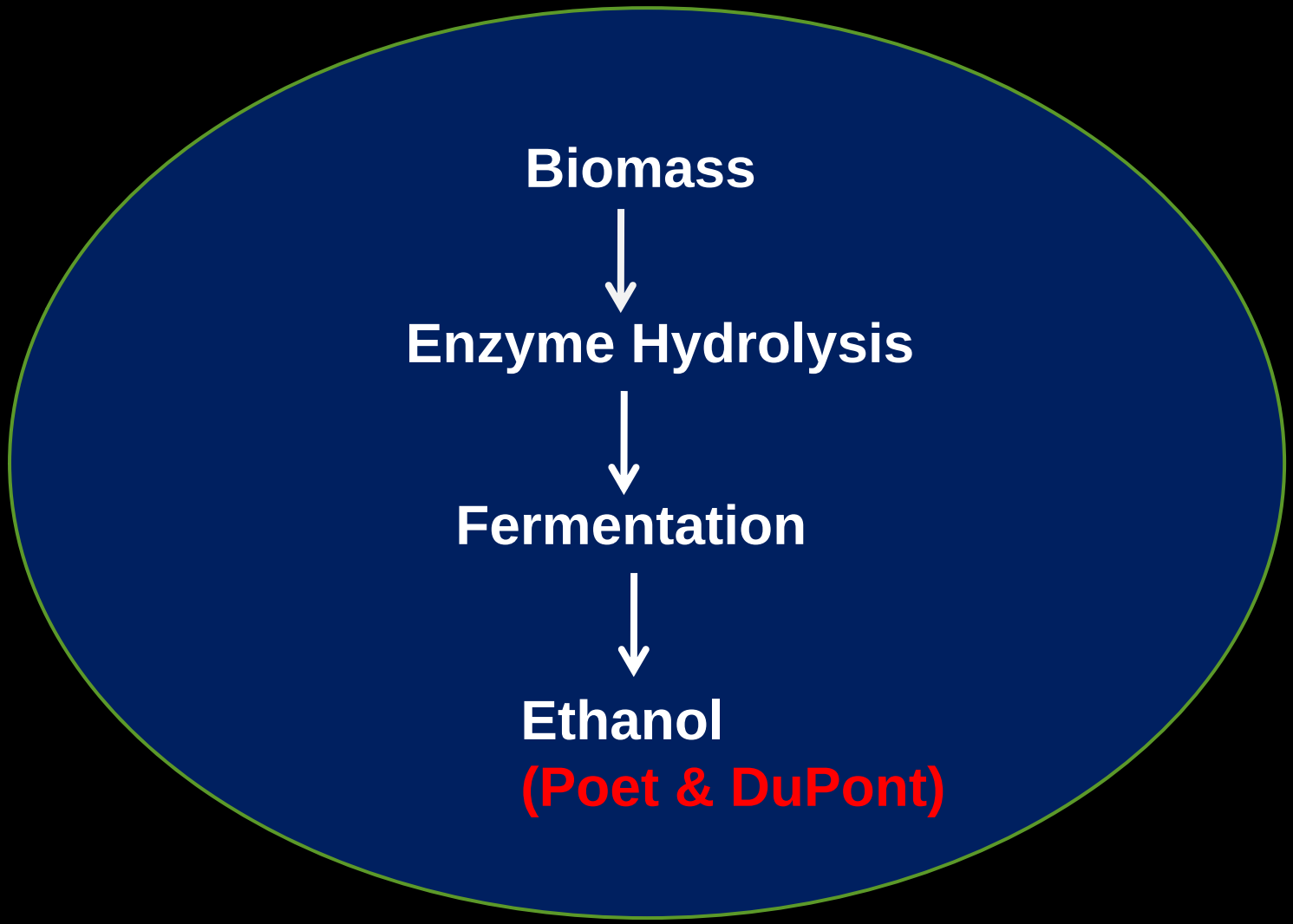
Bio-Chemical Conversion



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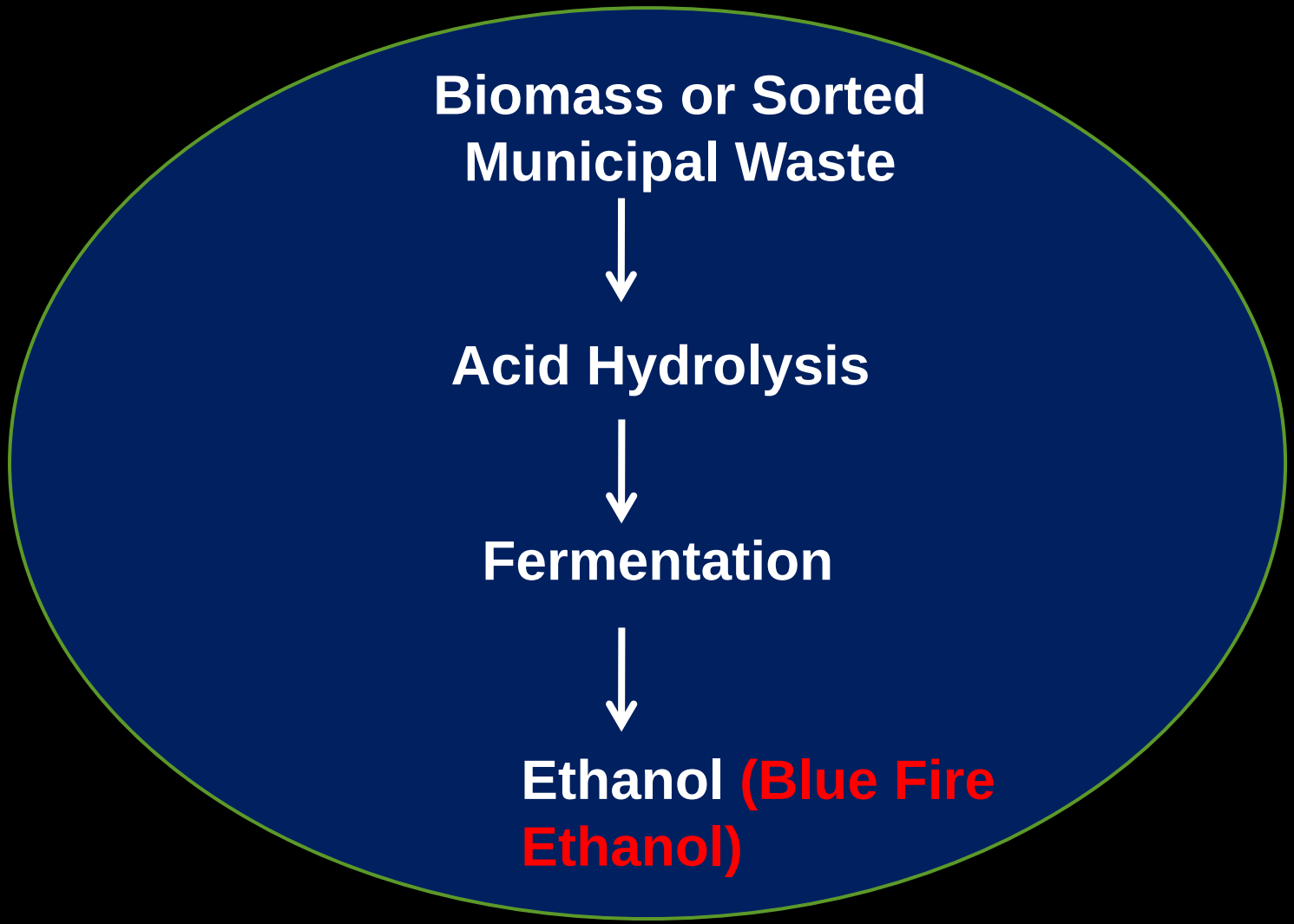

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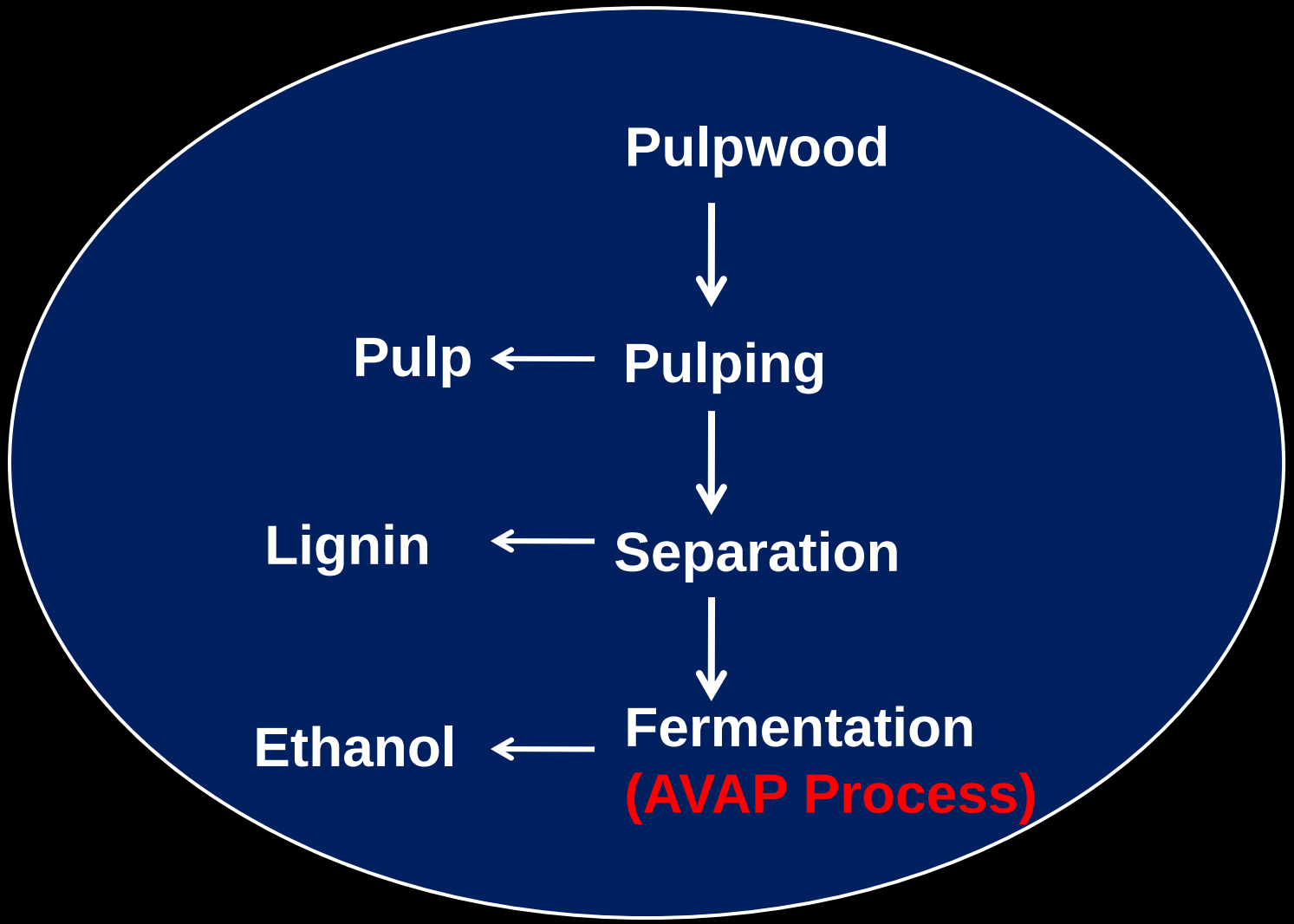
Bio-Chemical Conversion (Hemicelluloses)



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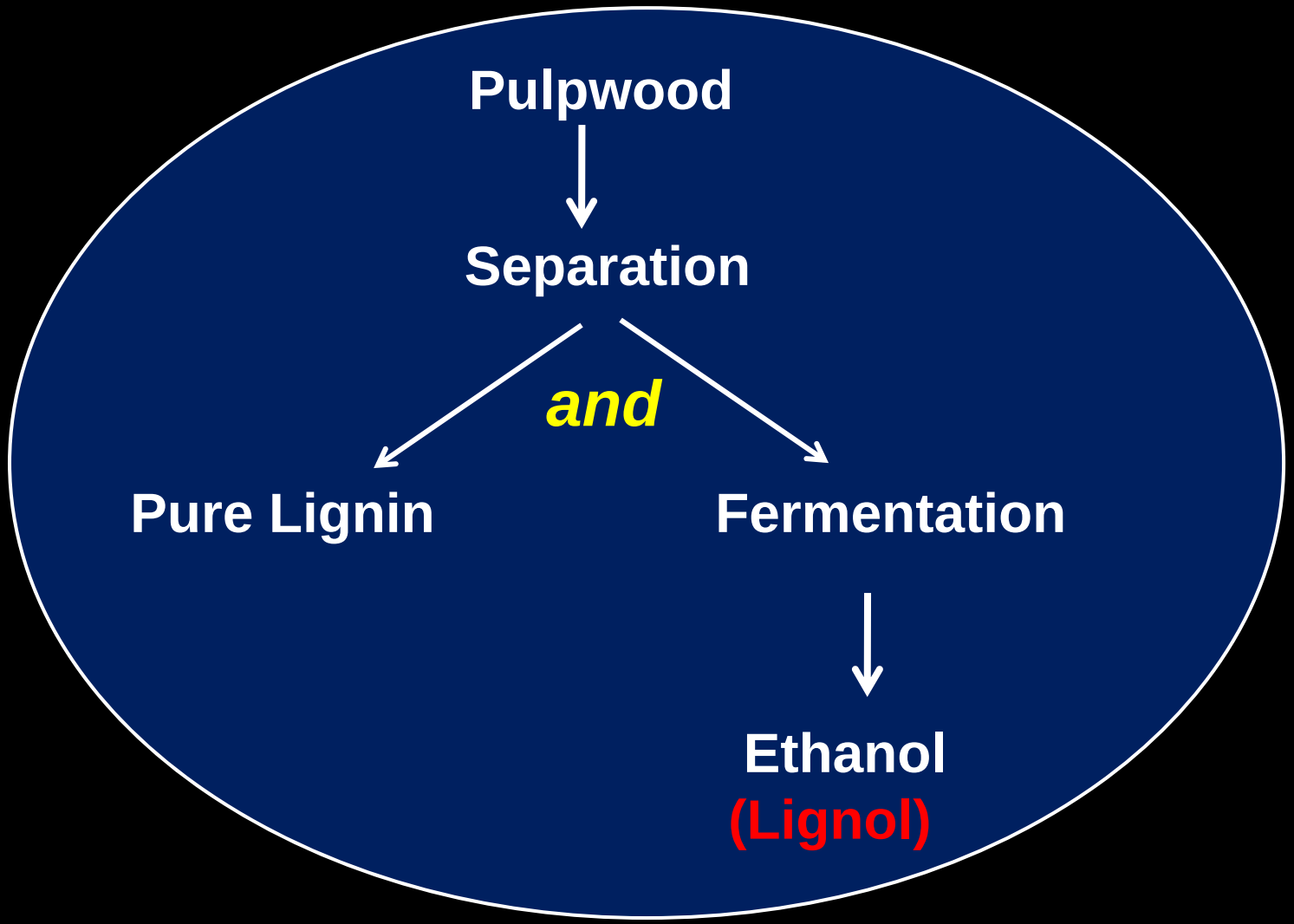

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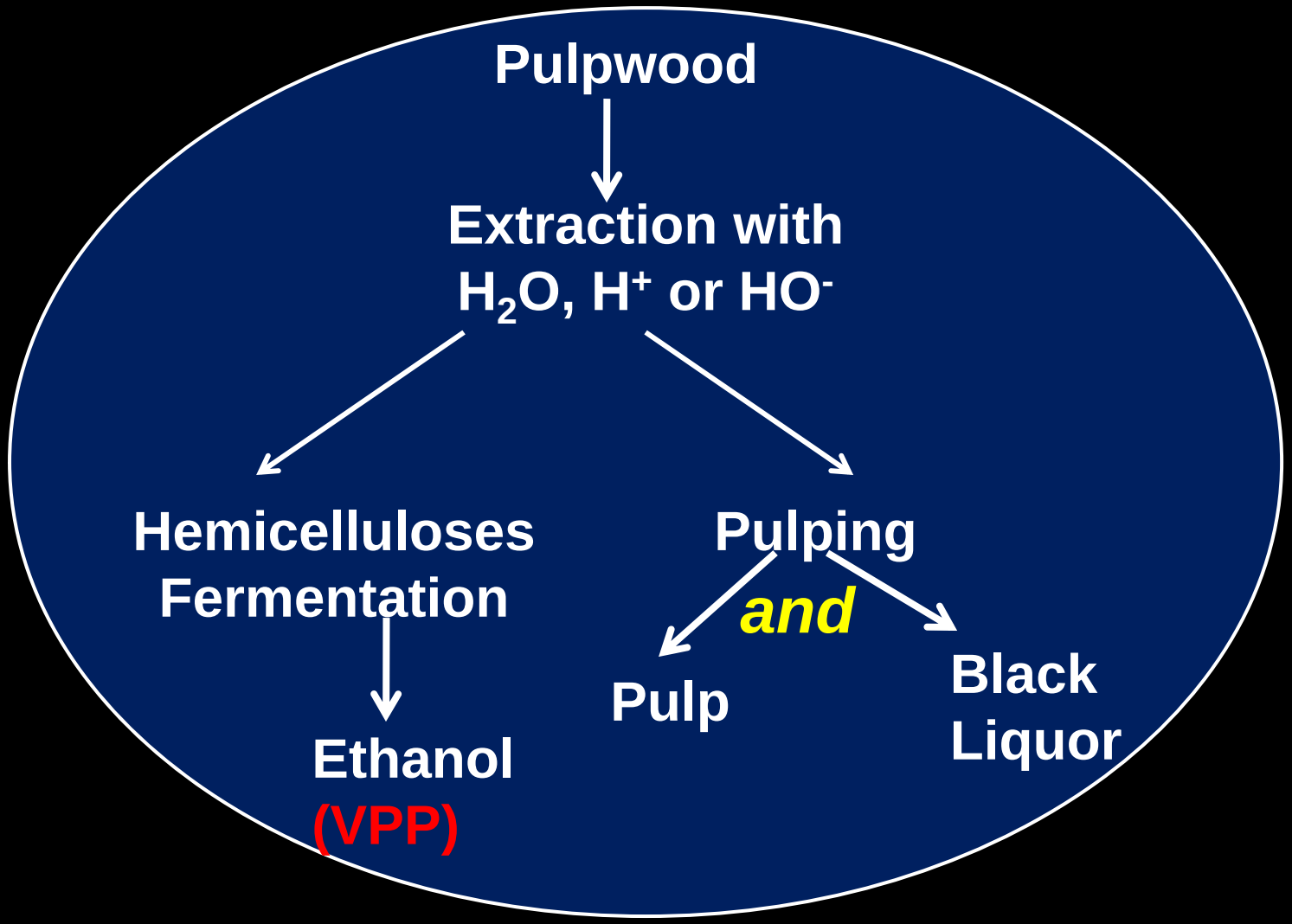

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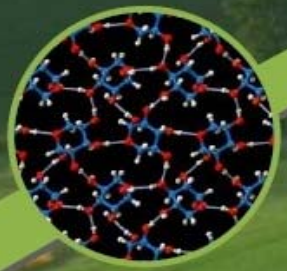
The Fundamental Science of Biomass Recalcitrance is Poorly Understood

Fuel(s)

Recalcitrance: Resistance to breakdown into sugars



Sugars

Overcoming recalcitrance is the single coherent overarching theme for the BESC

Cellulosic biomass

- A large-scale, integrated, interdisciplinary approach is needed to overcome this problem
  - Current research efforts are limited in scope
  - BESC will launch a broad and comprehensive attack on a scale well beyond any efforts to date
- Without advances, a cellulosic biofuels industry is unlikely to emerge
- Knowledge gained will benefit other biofuels and biofeedstocks

Ragauskas, A., III Seminar on pulp and paper: Biorefinery & biopulping and their impact on the pulp industry. Viçosa, MG, Brazil. April 11, 2008.

The BESC Team Assembled to Overcome Biomass Recalcitrance

Joint Institute for Biological Sciences

Alternative Fuels User Facility

- Oak Ridge National Laboratory
- University of Georgia
- University of Tennessee
- National Renewable Energy Laboratory
- Georgia Tech/IPST
- Samuel Roberts Noble Foundation
- Dartmouth
- ArborGen
- Diversa
- Mascoma
- Individuals from U California-Riverside, Cornell, Washington State, U Minnesota, NCSU, Brookhaven National Laboratory, Virginia Tech

Ragauskas, A., III Seminar on pulp and paper: Biorefinery & biopulping and their impact on the pulp industry. Viçosa, MG, Brazil. April 11, 2008.

Brazil's Bio-Refinery Potential

High Potential for Biomass Production

- Adequate climate
- Large available areas for cultivation
- Advanced forest and agricultural technologies
- Excellent adaptation of certain crops in the tropical climate
- Very high productivities
  - Sugar cane (80-90 ton/ha/year as such),
  - Bamboo (20-25 ton/ha/year dry),
  - Elephant grass (30-45 ton/ha/year dry)
  - Eucalypt (20-30 ton/ha/year dry)
- Biomass production costs are rather low

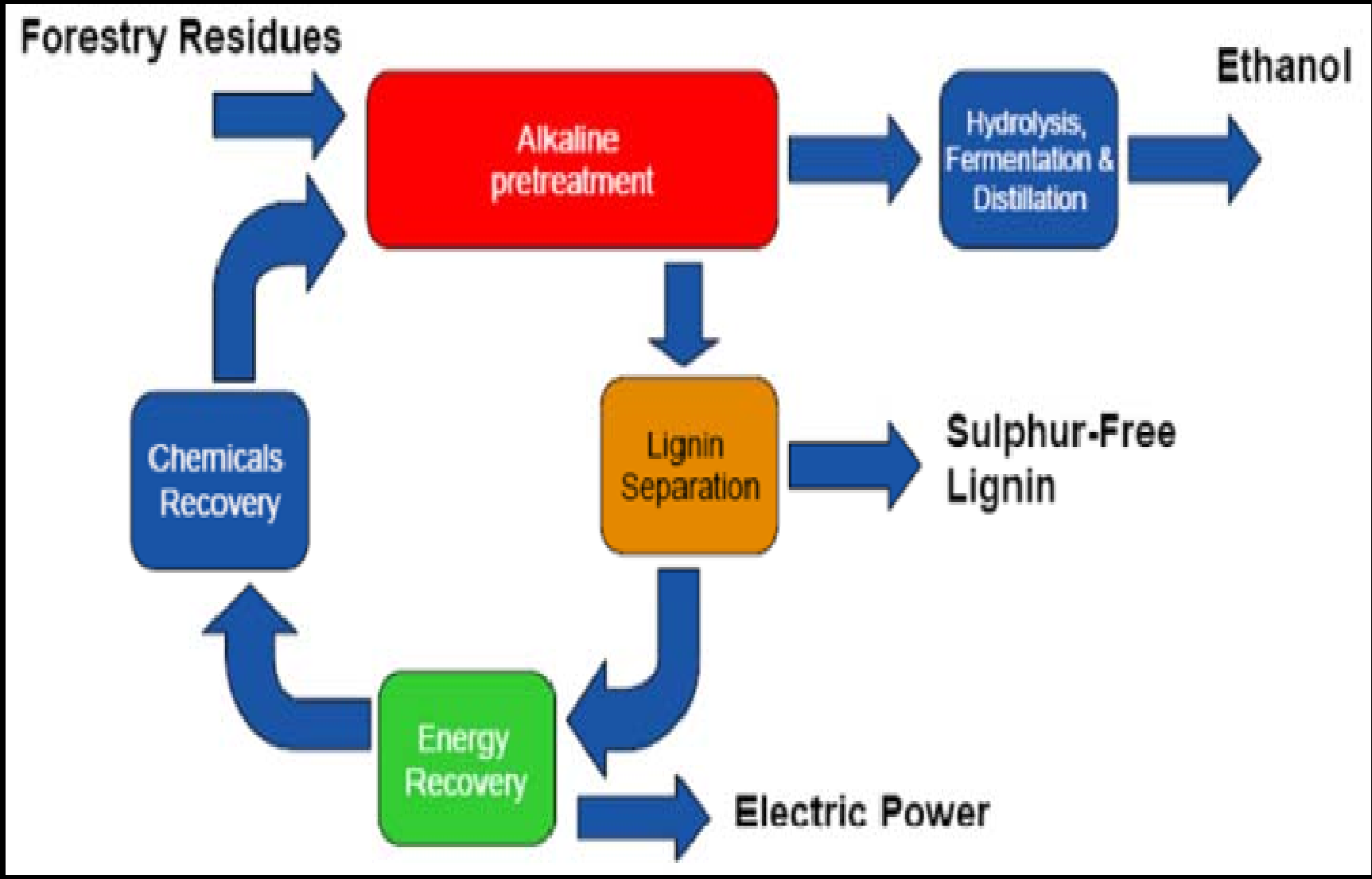
Biomass Deconstruction Challenges

- Partial deconstruction for paper pulp quite well known
- Deconstruction aimed at production of bio-fuels and bio-materials is still a great challenge
  - Limitations for enzymatic hydrolysis caused by the presence of lignin, acetic acid and other inhibitors

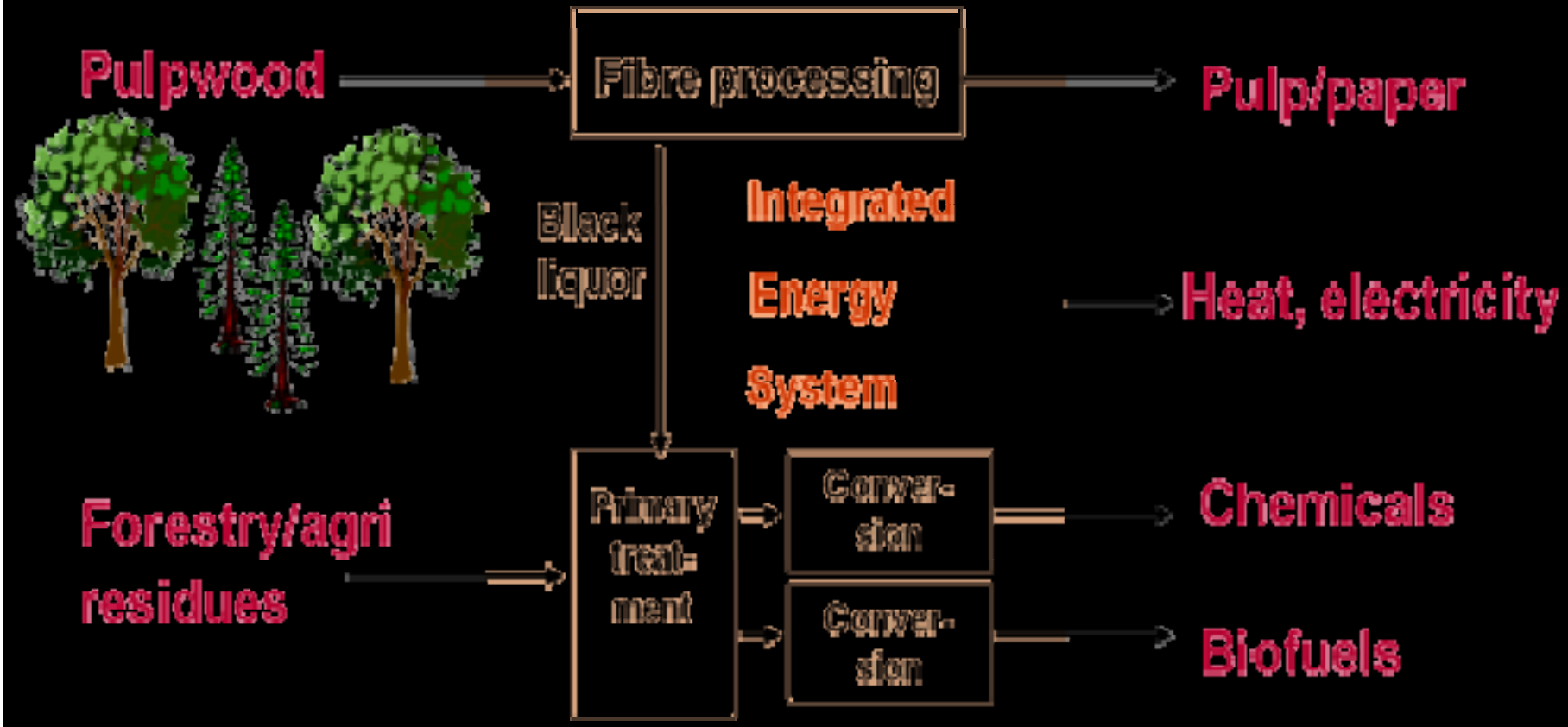
Biomass Deconstruction Pre-treatments

- Kraft process (sulfur issues)
- Acid sulfite
- **Soda and Soda-AQ**
- Organosolve
- AVAP
- Steam explosion
- Ammonium based processes
- etc.

The Non-sulfur Alkaline Route



The Pulp Mill Bio-Refinery According to Axegard, 2009



Profits Derived from Different Uses of Wood (Base: 500.000 adt/yr Pulp Mill)

Product	Profit , €/adt
Chemicals* - Succinic Acid	1054
Bleached Pulp** - softwood	134
Power/steam*** -LHV 8 MJ/kg and boiler efficiency of 87%	9
Biofuel**** -Ethanol	-62

*0.38 kg SA/adt; €4.00/kg SA;
**wood cost = €125/adt, fiber line yield = 41%;
***Power price = €0.04/kWh;
****910 liters of ethanol/adt, €0.38/L ethanol.

Biorefinery or Bio-Mania?

- Bio-refinery has been practiced for many years, particularly in the sulfite pulping industry
- However, energy/fuel high costs has prompted much larger efforts in making this concept work
- Many approaches being tried. Few will survive for lack of competitiveness
- Fuel route certainly will survive:
  - annual world increase in oil use exceeds annual new discovery rate (source :USA Federal Energy Council)
  - Legislations
- We need to find a way to capture solar energy directly rather than conveying it through biomass

Feedstocks

- All kinds of biomass, from wood and starches to agricultural residues
  - First generation sugars & starches: sugar cane, sugar beet, corn (maize) and wheat
  - First generation oleaginous: rapeseed (canola), jatropha, palm trees, etc.
  - Ligno-cellulosics: switch grass, elephant grass, sugar cane bagasse, corn stovers, cereal straws, wood, etc.