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Bio
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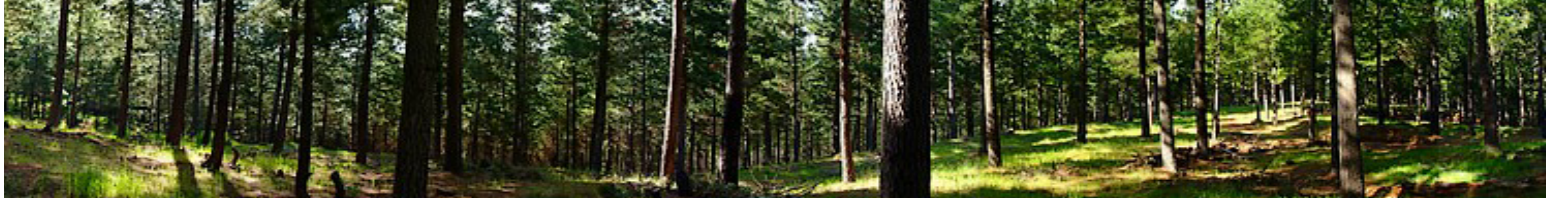
y 6 de mayo de 2009. Concepción, Chile.



MATERIALS FROM FOREST BIOMASS: AN OPPORTUNITY FOR CHILE

Saddys Rodríguez Ll., Cecilia Fuentealba, Juan C. Carrasco, Jaime Bravo,
Johana Castaño, Alejandro Zuñiga, Leonardo Olave, R.Medina and Ljubisa R. Radovic

Universidad de Concepción

UDT
UNIDAD DE DESARROLLO TECNOLOGICO

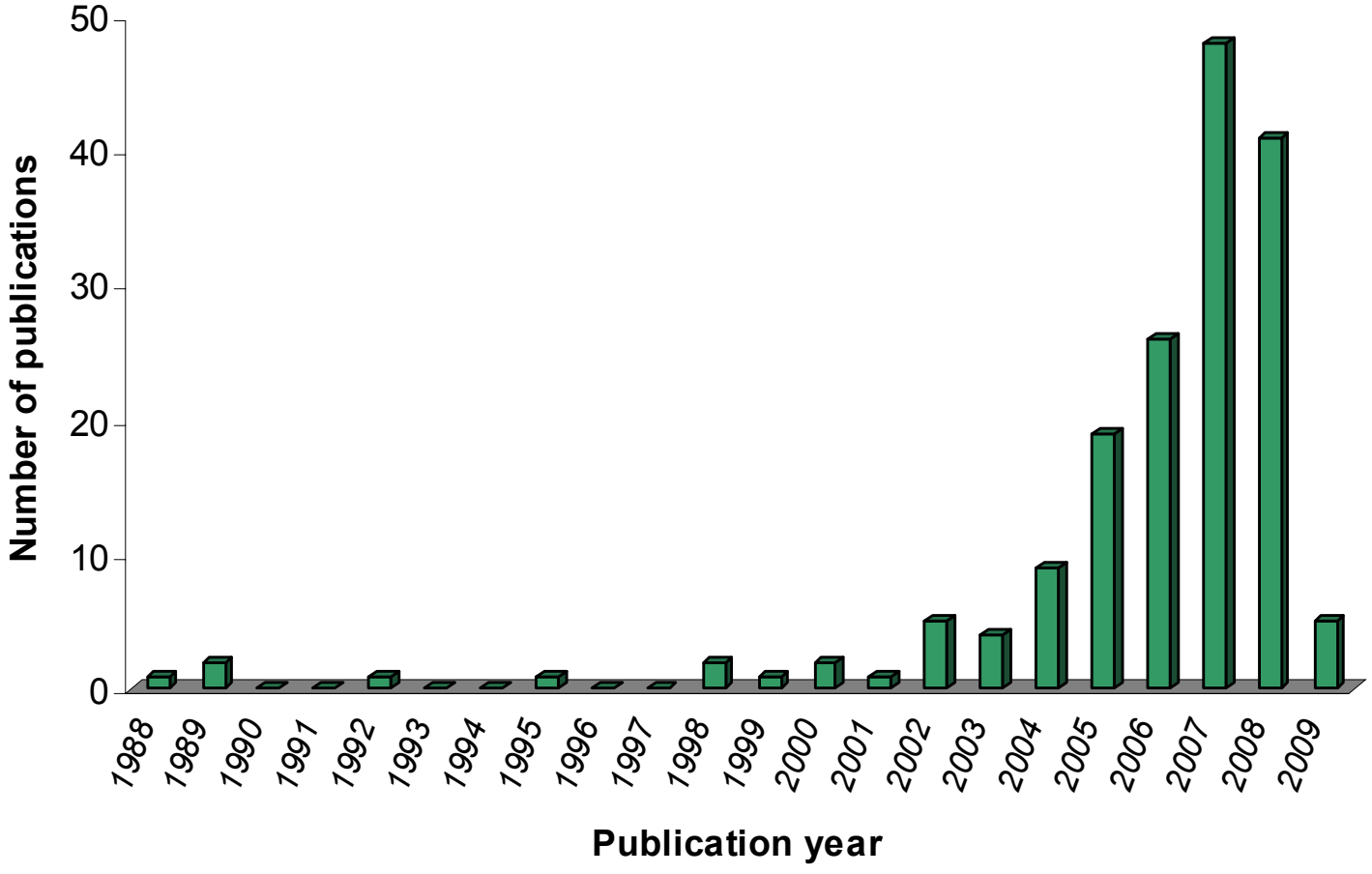


Fig. 1. Popularity of biorefineries as measured by the use of the term 'biorefinery' in the title of papers recorded by ISI's Web of Knowledge.

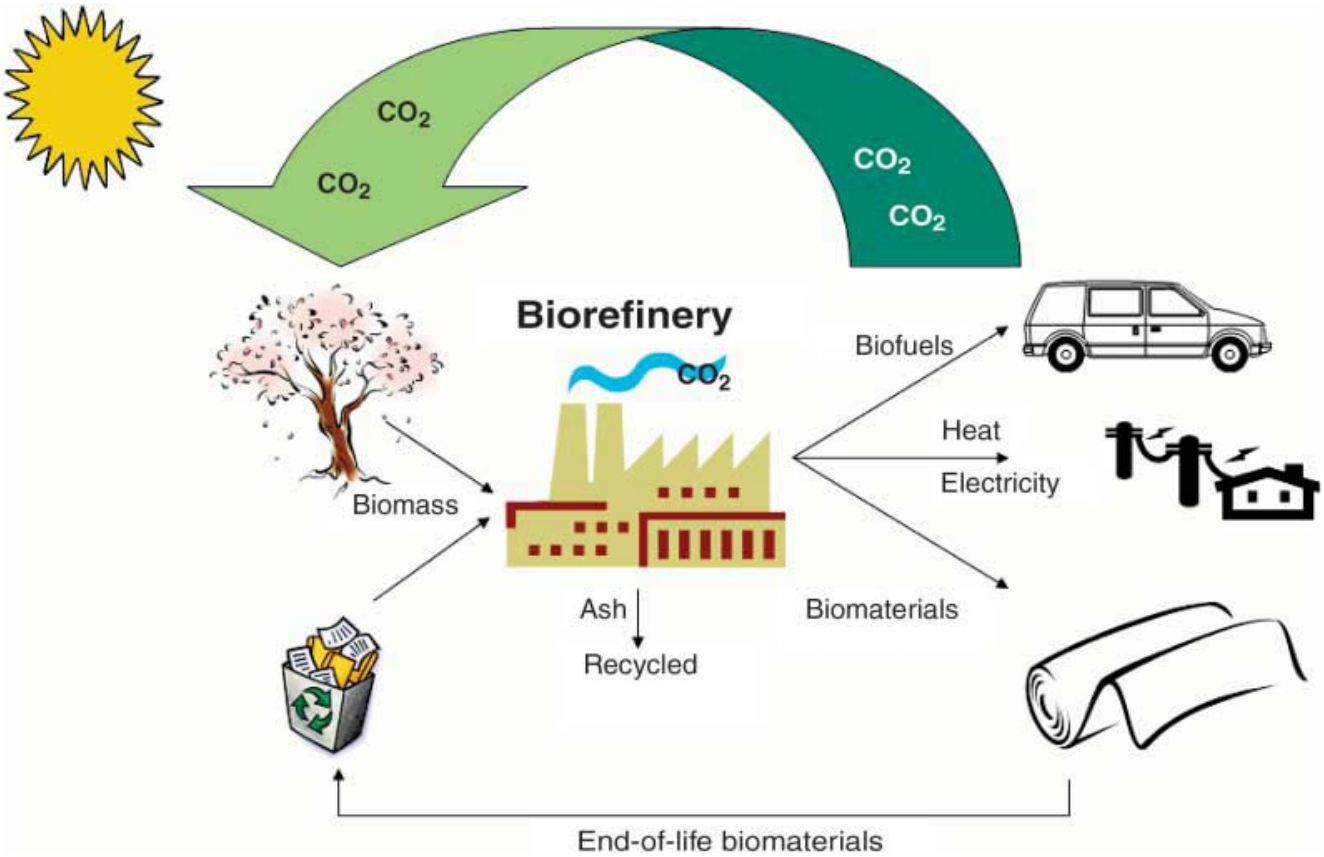


Fig. 2. The fully integrated agro-biofuel-biomaterial-biopower cycle for sustainable technologies.

Arthur J. Ragauskas, et al. Science 311, 484 (2006)

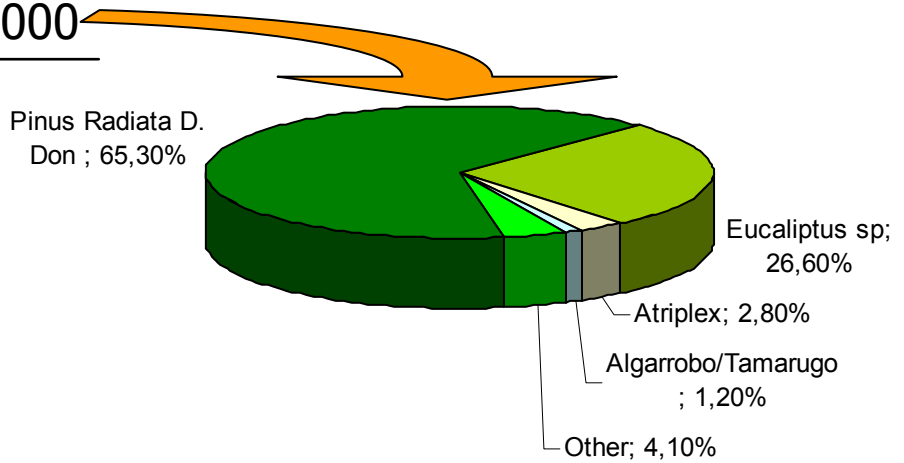
Biorefinery systems

- The “Whole Crop Biorefinery” uses raw material such as cereals or maize.
- the “Green Biorefineries” using “nature-wet” biomasses such as green grass, alfalfa, clover, or immature cereal.
- The “Lignocellulosic Feedstock Biorefinery” using “nature-dry” raw material such as cellulose-containing biomass and wastes.

Birgit Kamm et al. Forum der Forschung 19/2006: 53-62

Table 1. Surface coverage of native forests and forest plantations in Chile.

Type	Surface (ha)
Total	15.951.600
Native forests	13.650.433
Mature forests	5.936.128
Regrowth	3.757.491
Nature-regrowth forests	894.814
Krummholz	2.975.386
Mixed forests	86.611
Forest plantations	2.200.000



Boletín Estadístico 117, Estadísticas Forestales Chilenas 2006, INFOR, Gobierno de Chile
Medio ambiente. Informe anual 2005, Instituto Nacional de Estadísticas, Chile

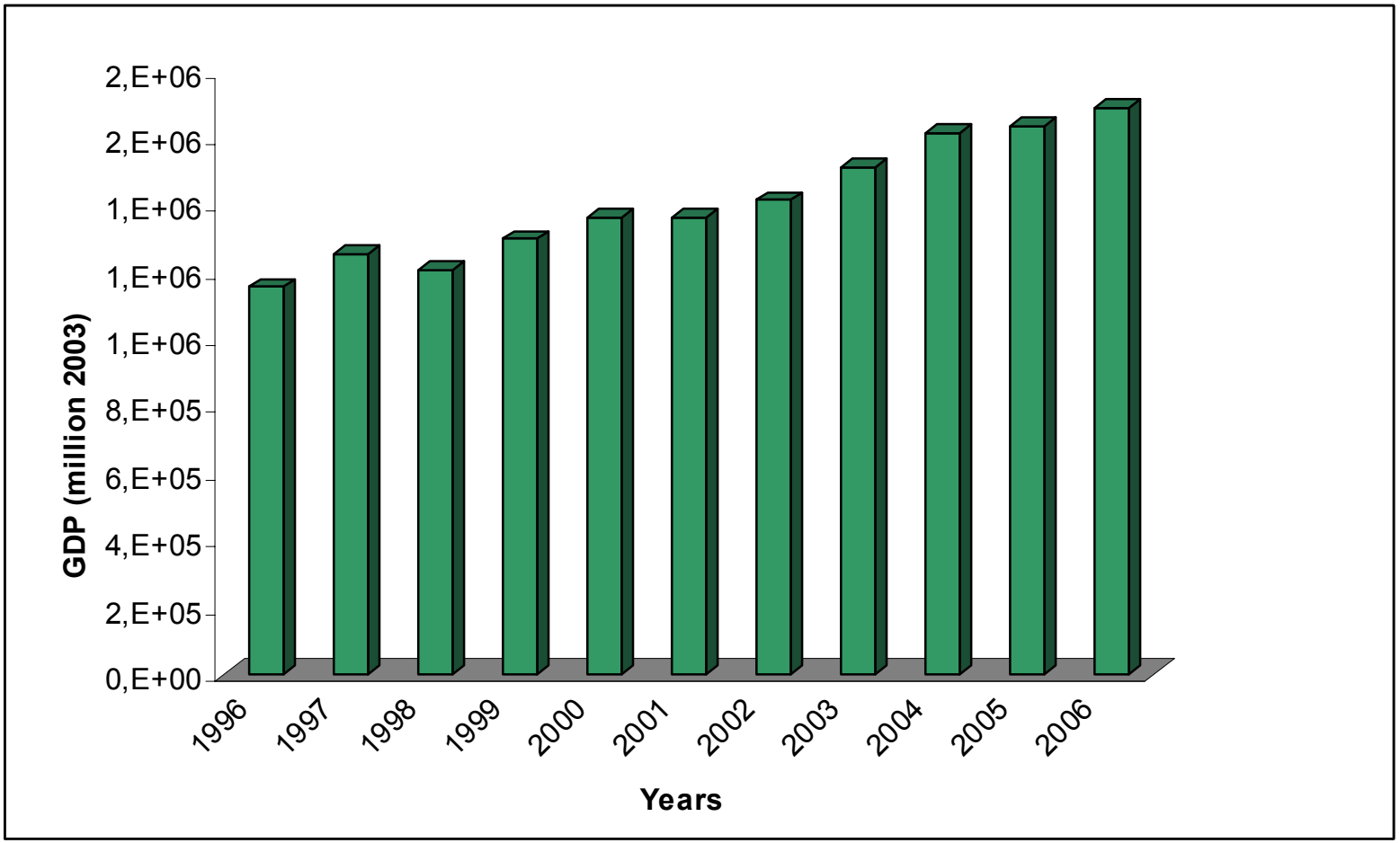


Fig. 3. Gross Domestic Product of the forest sector in Chile (including forestry, wood industry, and pulp and paper industry) between 1996-2006.

Boletín Estadístico 117, Estadísticas Forestales Chilenas 2006, INFOR, Gobierno de Chile

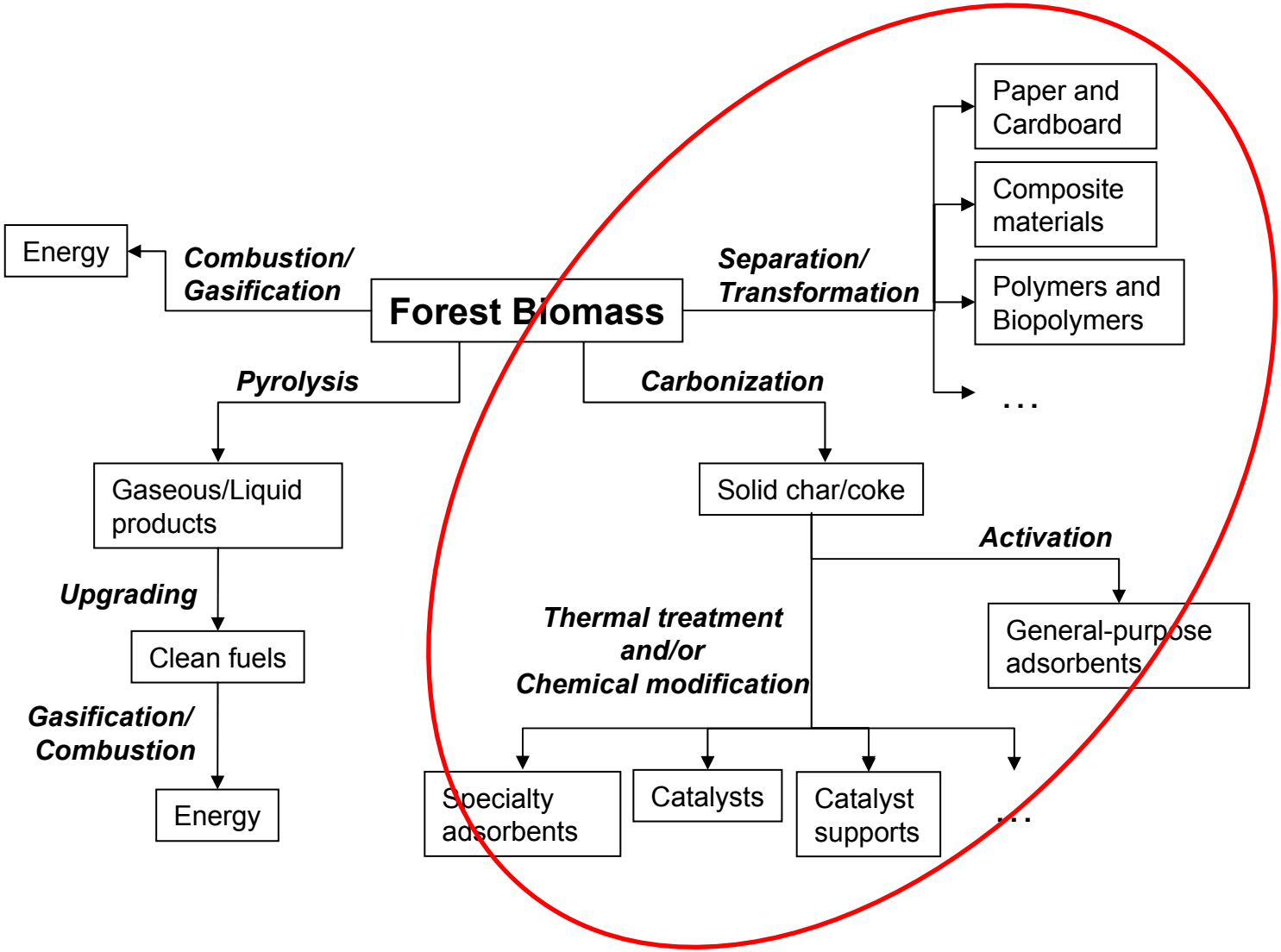


Fig. 4. A biorefinery for the 21st century: integrated production of materials, chemicals and fuels.

Paper and Cardboard

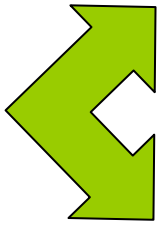
Table 2. Global market of the pulp during 2008

Country	Market Pulp Capacity (MT)
Canada	10.578
United State	8.932
Brazil	8.570
Chile	**4.650**
Sweden	3.785
Indonesia	3.460
Finland	3.015
Russian	2.630
Spain	1.350
Portugal	1.185

Referencia, Bolletín Celulosa and papel, CMPC, 2008

Paper and Cardboard

- 90% of the worldwide cellulose production comes from fibers of forest biomass
- Traditional pulp mills



< 50% Pulp

Black liquor

Burn

Recovering the cooking Chemicals

Steam and electricity

Paper and Cardboard

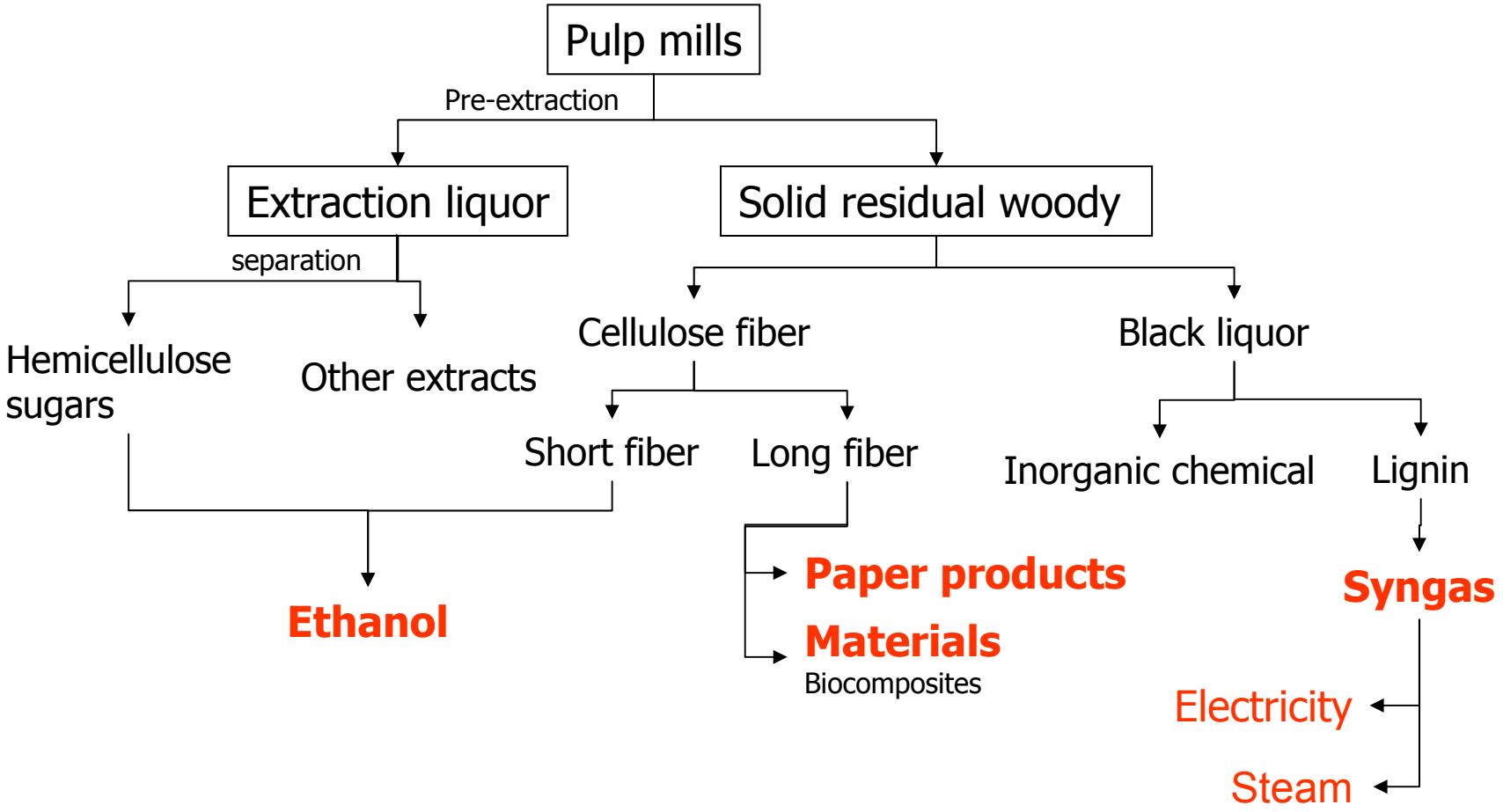


Fig. 5. Diagram of an integrated forest biorefinery based on the existing pulp mills.

H.J. Huang et al. Separation and Purification technology 62 (2008) 1

Derivative products of forest biomass

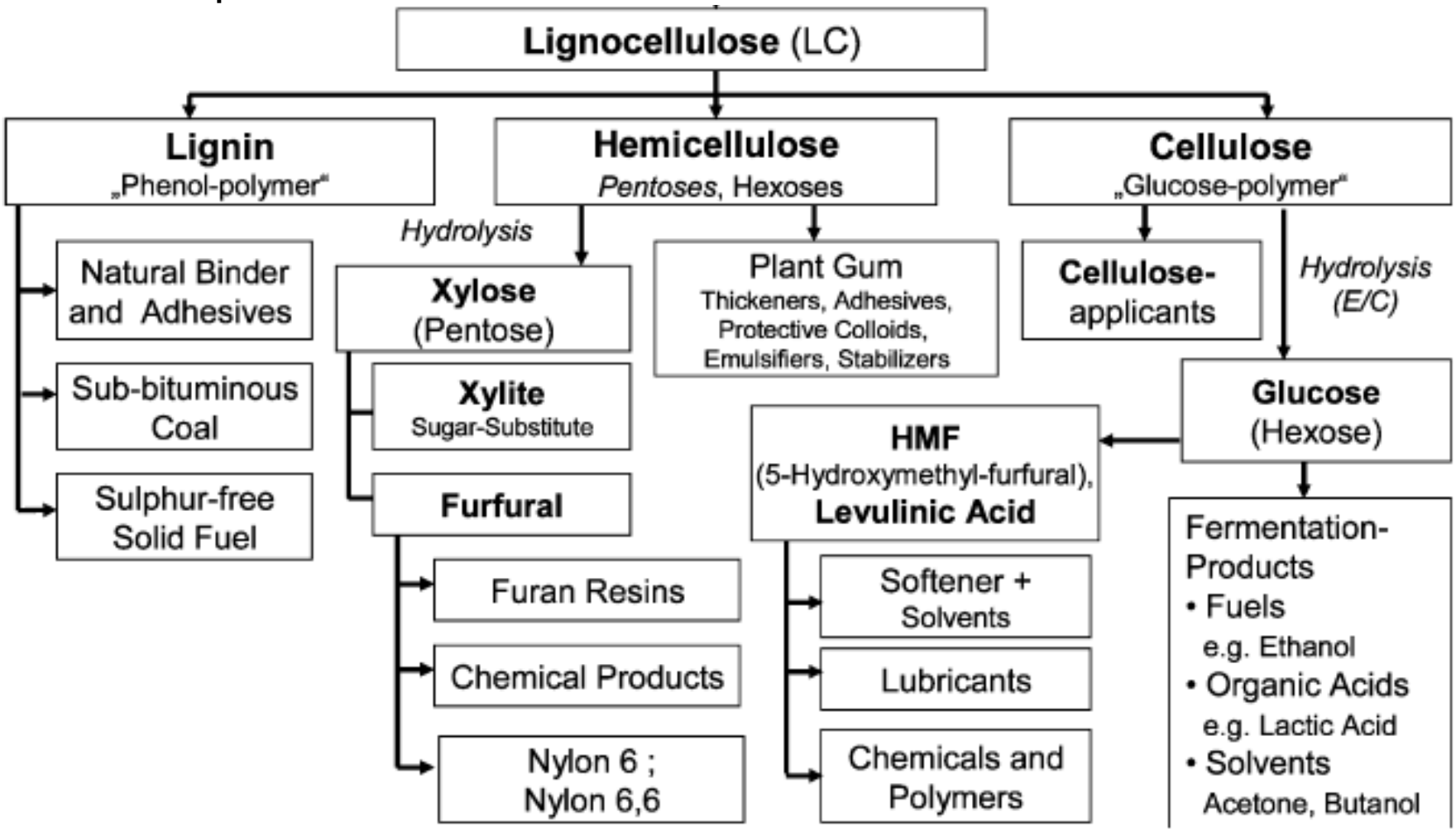
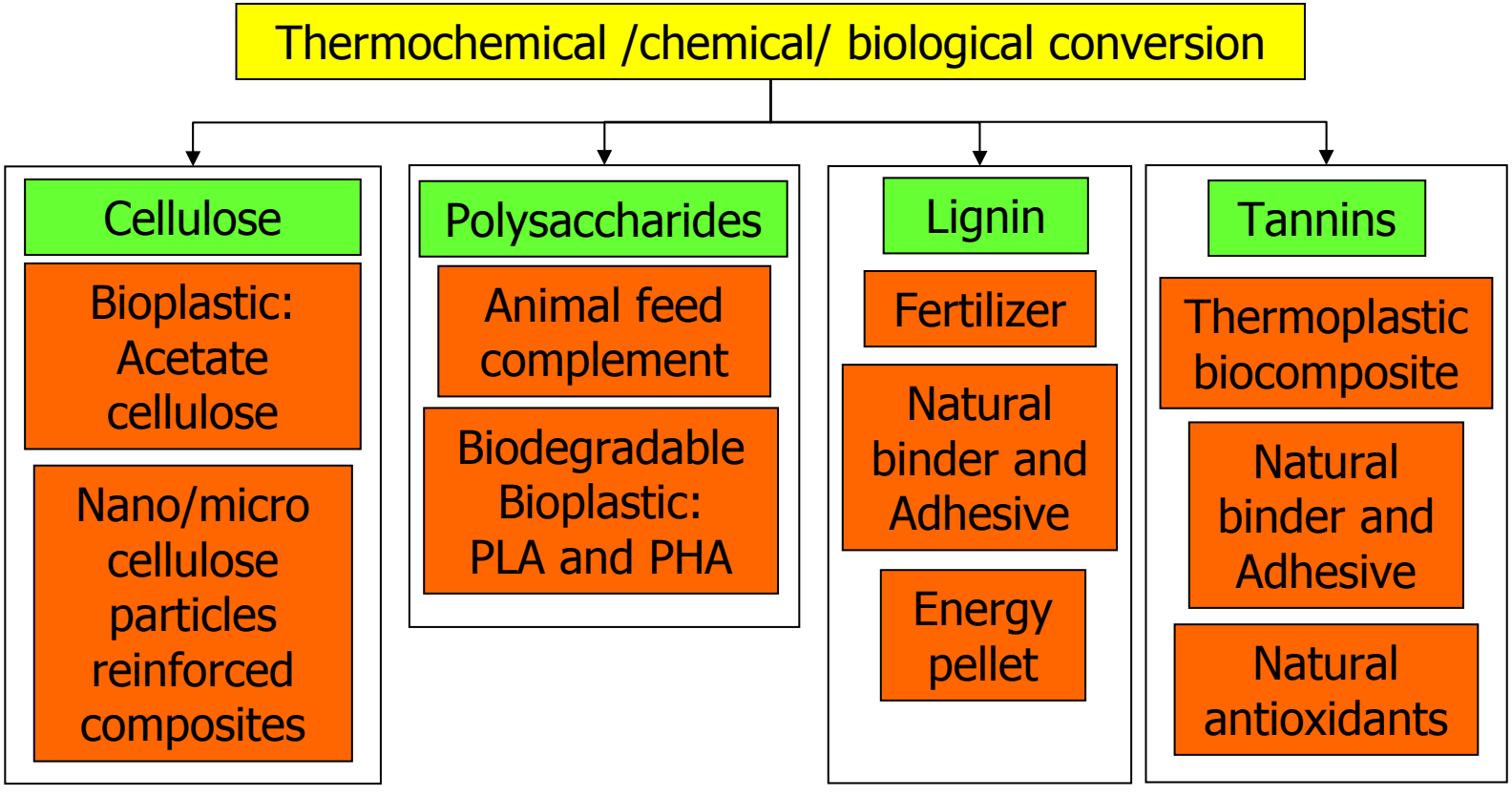


Fig. 6. Lignocellulosic Feedstock Biorefinery.

Appl Microbiol Biotechnol (2004) 64: 137–145

Line development from forest biomass



Bio-derived plastics

Polylactic acid

Fermentation process of corn dextrose

Chemical synthesis from acetaldehyde and hydrogen cyanide

Economically competitive

Poly(trimethylene terephtalate)

1,3 propanediol
Fermentation process of carbohydrates

Nylon 6 and Nylon 6,6

Furfural and hydroxylmethylfurfural
Sugar deshydratation product

Synthesis of polylactic acid (PHA)

Fig. 7. Bioreactor for fermentation.

Sugar mixture —*Lactocaccus lactis* subp, *cremoris* y *Lactococcus lactis* subsp. *lactis*.→ **PLA**

Fig. 8. Biodegradable container for forestry

Cellulose-applicants

Cellulose Nanowiskers from forest biomass (CNW)

- Whisker-like nanostructures enhance mechanical properties.
- CNW are a nanofiller derived from renewable biomass.

→ The dimension of the CNW dependes on the sample origin
- Wood sources: 100-300 nm in length; 3-10 nm in width
- Crystal modulus: 138-167 GPa (100 times greater than a typical glassy polymer)

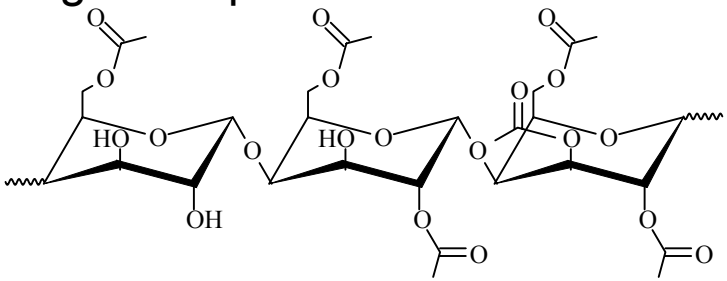
→ Researches are focalized
- Efficient separation of the nanowisker from wood
- Compatibilization of nanoreinforcements with the matrix
- Development of the suitable methods for processing

H. Chanzy, Aspects of cellulose structure. Ellis Horwood Ltd, New York (1990).
Goetz et al. Carbohydrate Polymers, 75, 2009.

Cellulose-applicants

Cellulose acetate:

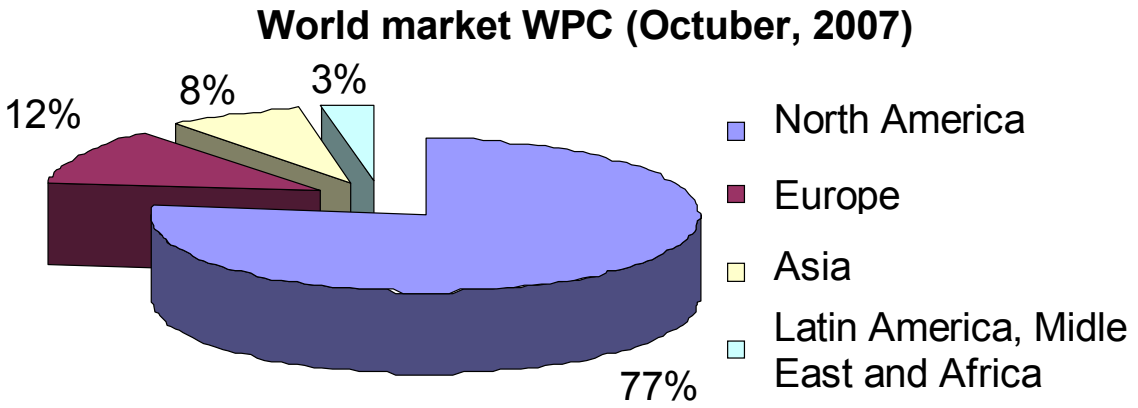
- In 1985 was synthesized by Schützenberger for heating cellulose with acetic anhydride.
- Celullose alpha > 95% with low level of impurities, specially, hemicelluloses.
- High cost production cost

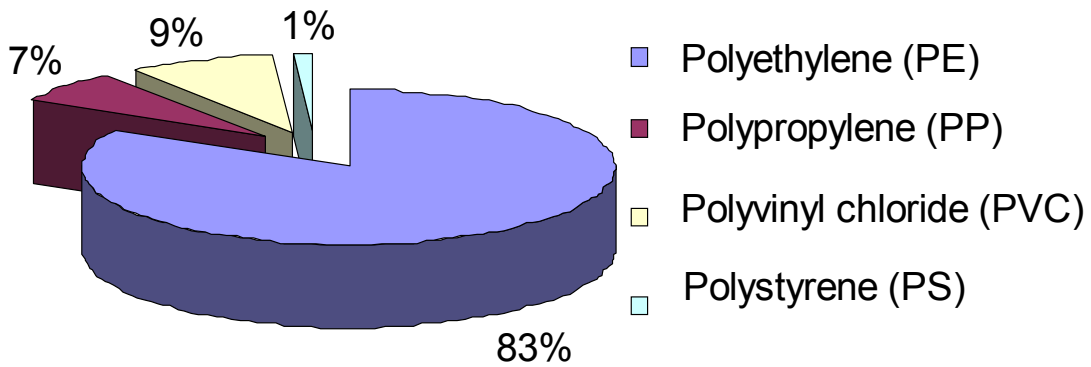


Cellulose as a plastic

- 1910 – AC was used in the photographic films production
- Prepare in different forms, like a bars, sheets, tubes.
- En 1927 a moulding powder compound became available which could be transformed quickly and cheaply through injection moulding.
- The diffusion of the numerous applications of acetate reached its peak in the 1960's: boxes, blisters, food packing.

Wood Plastic Composite (WPC)





Compuestos de Madera Plástica para la Construcción. Perspectivas y Oportunidades. Dr. Roberto Lopez-Anido, P.E. University of Maine.

Wood Plastic Composite

Polyolefin

WPC

Lignoplast firm

Fig. 9. Twin screw extruder TSA Industriale (L/D 40)

Tecnologías del plástico, 09 (2006)

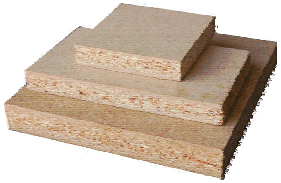


Table 3. Export cuantity in chile during 2008.

Wood-based panels	(Ton)
Middle density fiber board (MDF) [1]	430.819
Plywood[1]	465.656
Oriented strand board (OSB)[2]	79.893
Particle boards[2]	44.101

[1] *INFOR, mercado forestal n°36*

[2] *ODEPA, informe regional de exportaciones silvoagropecuarias, avance mensual enero 2009*

Tannin

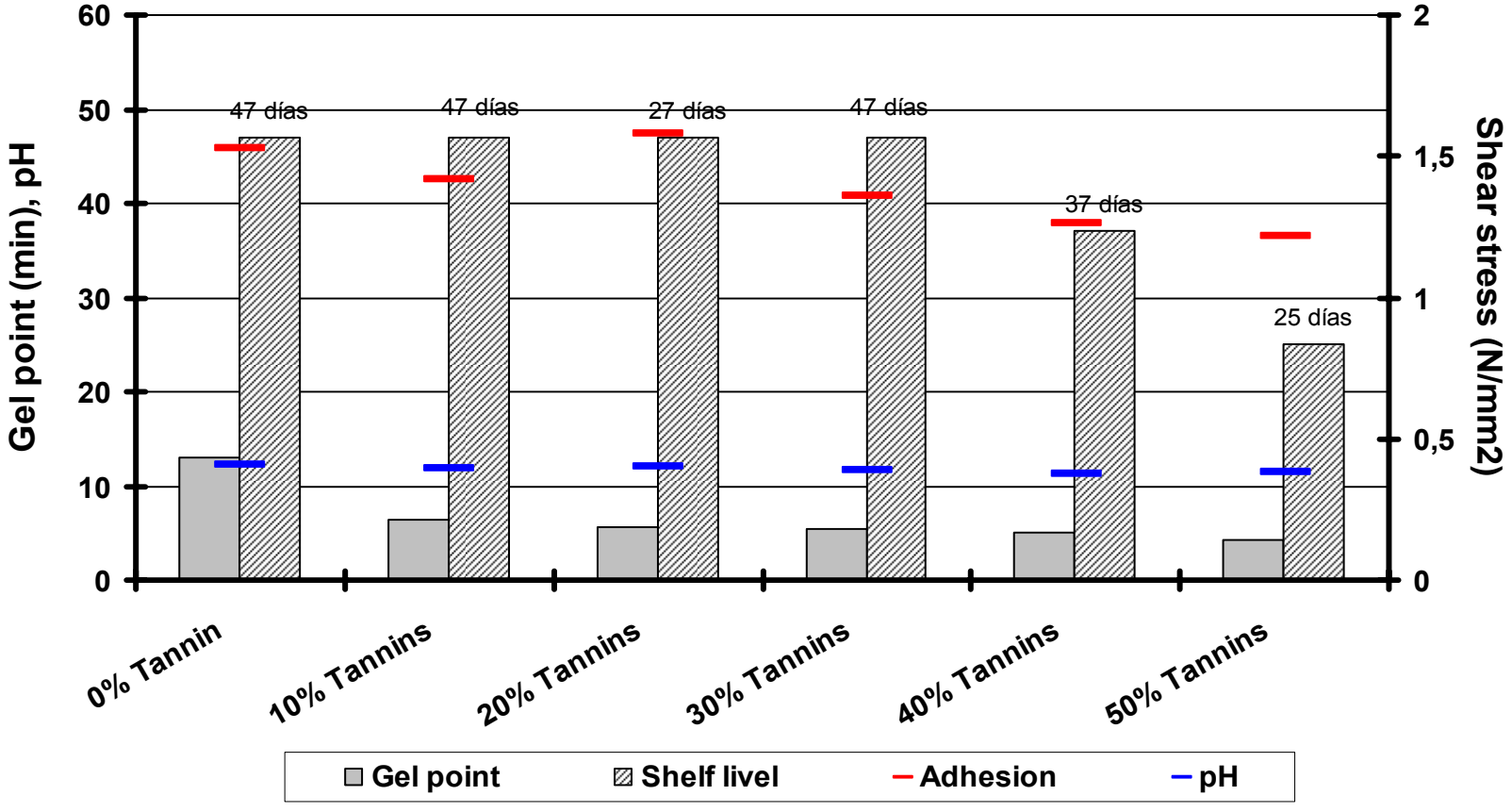


Fig. 10. Effect of tannins addition on gel point, shelf live and mechanical propeties adhesive resins

Carbonization Process

Charcoal

- Higher calorific value
- Effective adsorbent

Carbon molecular sieves[1] → Eucalyptus globulus → Gas mixture separation CH_4/CO_2 and C_3H_8/C_3H_6

R. García et al. Microporous and Mesoporous Materials 81 (2005) 161–167

This requires close interdisciplinary collaboration of chemical and mechanical (and other) engineers!!!

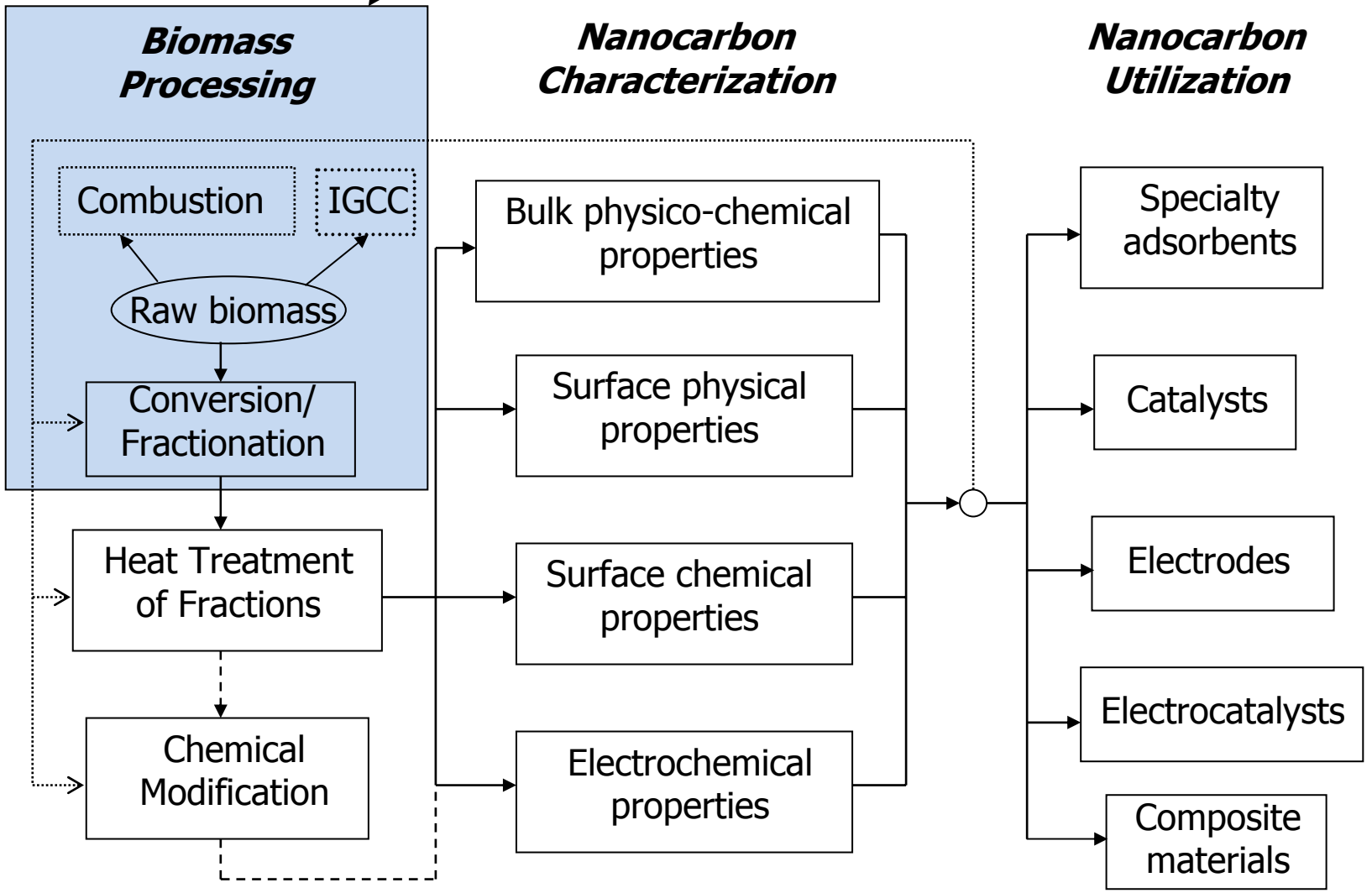
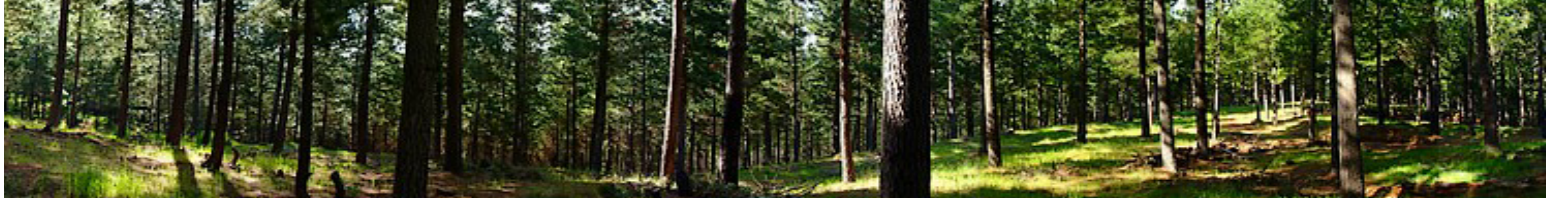


Fig. 11. Schematic representation of a modern "biomass refinery," emphasizing product- and process-optimization feedback mechanisms.

Summary

- Emerging vision for forest biorefinery is a modified mill that manufactures a diversified set of products which may include pulp and paper.
- Biggest growth opportunity for integrated biorefinery will be a judicious balance between the production of fuels, chemicals and materials.
- Commercialize ALL the products! Add value to ALL the products!



Gracias