The U.S. Pulp and Paper Industry:
A Key Player in the Coming Bio-revolution

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Introduction

Throughout the twentieth century the U.S. pulp and paper industry supplied domestic markets while also serving global markets as a net exporter. It was, and remains, the world's largest pulp and paper industry.

In recent decades, however, fortunes have begun to change. Despite the fact that paper and paperboard consumption has more than doubled in the United States since 1970 and increased almost 40 percent since the late 1980s, there have been no new domestic paper mills constructed since 1989, and no new paper machines brought on line since the mid 1990s. Overall, domestic paper and paperboard manufacturing capacity declined from 2000 through 2003 at an average annual rate of 0.6 percent, the first period of consecutive year declines in manufacturing capacity in U.S. papermaking history. While it appears that renewed modest investment in the U.S. paper and paperboard industry may occur over the next several years (growth of 0.7 percent in manufacturing capacity was recorded in 2004), further losses in paper mill employment and production capacity are likely.

Declining domestic production has been more than offset by a growing global production capacity. Since 1970, worldwide paper consumption has increased over 150 percent, while pulp and paper manufacturing capacity has increased by an even greater percentage.

In response to the challenge posed by global competition, the domestic paper industry has identified a new strategic direction and embarked on an aggressive research initiative in cooperation with the U.S. Department of Energy and a number of universities. The strategy is to convert existing pulp and paper mills to full bio-refineries, capable of producing not only pulp and paper, but bio-fuels, bio-chemicals, and bio-feedstocks as well.

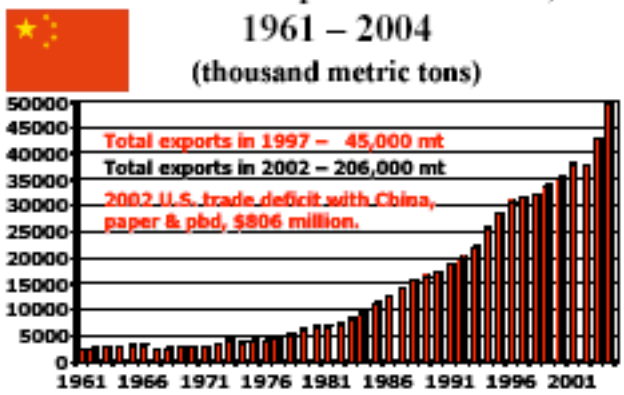
Global Challenges, Energy Issues Drive Change

A number of factors are pressuring domestic pulp and paper manufacturers. These include the following:

- Marked growth of forest products production capacity, including paper production capacity, within China over the past several decades (Figure 1).

  This growth in China's capacity is likely to continue. China has reportedly embarked on a $25 billion plan to enhance wood-based pulp mill capacity through the establishment of 12.5 million acres of tree plantations and construction of 42 large-scale pulp and paper mills by 2010.

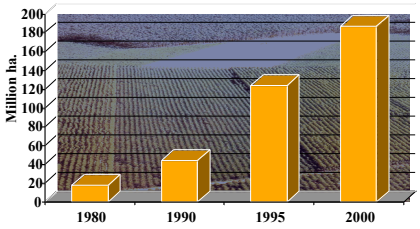
Figure 1
China's Paper Production, 1961 – 2004
(thousand metric tons)



Source: United Nations Statistics, 2005; trade deficit data from Paper Age, July, 2003.

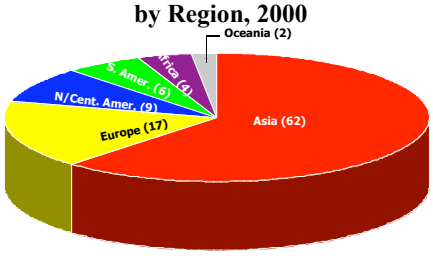
- An ongoing pattern of investment in new mills and mill modernization in northern Europe.
- A large and ongoing trade deficit with China that translates to a virtual river of shipping containers that would return to China empty were it not for their use in conveying basic raw materials such as wastepaper.
- Massive investment in tree plantations in Asia and other regions outside North America, leading to increasing availability worldwide of low-cost wood fiber (Figures 2 and 3).

Figure 2
Area of Wood Fiber Plantations Globally, 1980-2000



Source: Brooks, 2001.

Figure 3
Percent of Forest Plantation Area Globally by Region, 2000



Source: FAO, 2001.

- Increasing wood fiber costs in North America.
- A lack of significant investment for more than a decade on the part of the domestic industry in new production facilities and process control technologies and systems.

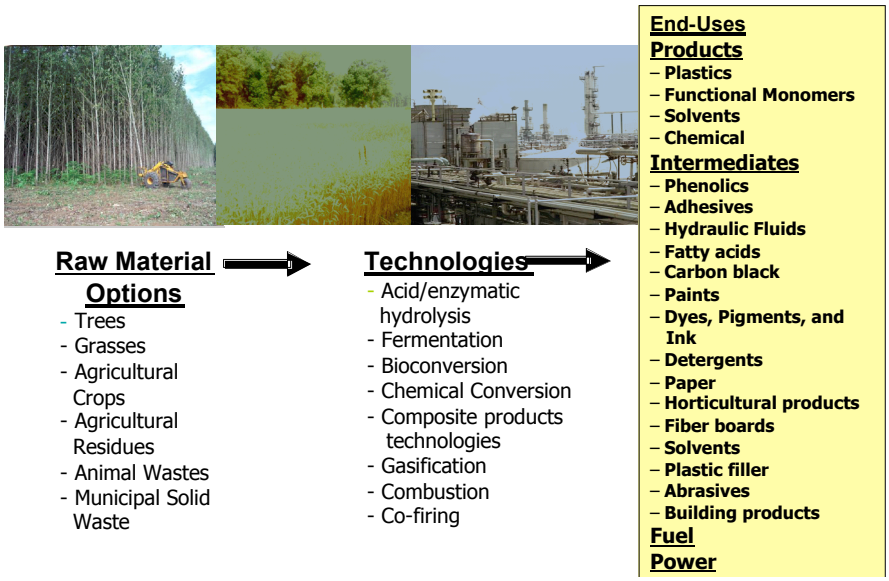
In short, a number of major trends nationally and globally are converging to place stress on the domestic pulp and paper industry. It is often the case that stress drives change, and in this case the changes that lie ahead may literally transform the U.S. paper and paperboard industry.

A Bio-Revolution is Coming – But What the Heck is a Bio-Revolution Anyway?

A bio-economy has been defined as an economy where the basic building blocks for industry and the raw materials for energy are derived from plant/crop-based (i.e. renewable) sources. Many products are produced from trees today by the forest products industry. Others are produced by the agricultural sector. However, there is far greater potential for production of bio-products than is currently being realized. Using a variety of bio-based materials, from forest thinnings and crop residues to animal and human wastes, and using an array of current and developing technologies it is possible to produce a wide array of products, including power, liquid fuels, chemicals, and chemical feedstocks (Figure 4). In the course of the coming bio-revolution there will be a relatively rapid shift to reliance on plant and crop-based resources for a significant portion of energy and chemical products.

Figure 4

An Integrated Bio -Economy Has Many Facets



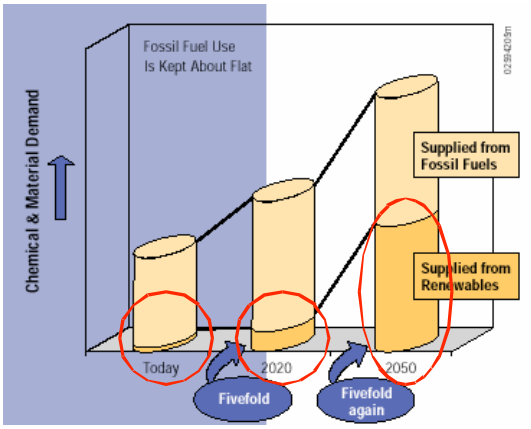
Source: Adapted From Iowa Industries of the Future, 2004.

While it is unlikely that renewable materials will provide all of the basic building blocks of the future economy, rising concern about future supplies of petroleum is stimulating interest and investment in potential alternatives. The future will bring an increasing need for substitutes for both transportation fuel and a number of non-fuel products now produced from petroleum. Plants can provide a substantial quantity of both fuels and non-fuel products.

A 1999 industrial chemicals and materials future scenario developed by the U.S. Department of Energy provides an example of what may lie ahead. The authors envisioned that 10 percent of industrial chemicals and materials would come from renewable resources by 2020 (~$400 billion/year in products – 2 times current forest products), with as much as 45-50 percent from renewable sources by 2050 (Figure 5).

More recently, the U.S. Departments of Energy and Agriculture have announced a goal of producing a sustainable supply of biomass sufficient to displace 30 percent or more or the country's present petroleum consumption.

Figure 5
Bio-economy – the Future is Now



Chemical and Material Demand 10% from Renewable Resources by 202 0
~$400 billion/year in products (2 times current Forest Products)

Source: U.S. DOE, 1999.

Given the dramatic developments occurring relative to renewable materials, it is perhaps fitting to describe what is coming in theatrical terms: *The music has begun, the actors are in place, and the curtain is about to rise for the first act of* ***Bio-revolution****. In view of the extensive preparation over a period of many years it should be a great show. Time will tell if the reviews turn out to be as positive as the advance publicity!*

The North American Pulp and Paper Industry – a Transformation Lies Ahead

Current Operations – the Focus is Paper

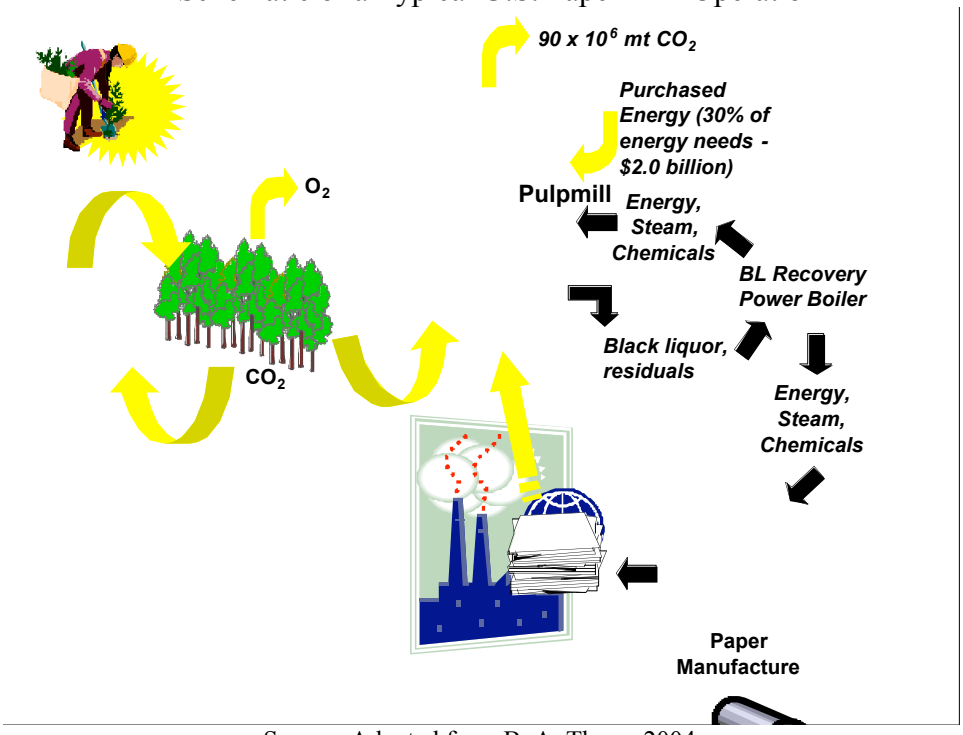
Today's paper mill is a marvel of engineering. On a massive scale, wood is broken into constituent fibers, and unwanted components are separated and used for production of energy to power the production process. Pulping chemicals are reused again and again. Then, fibers are laid into a mat, the thickness of which is controlled in a range of a few thousandths of an inch, often at speeds of up to 40-65 miles an hour.

From the shipping dock of a modern mill, large rolls of paper are moved to all segments of society, providing an essential element for everyday life. The range of products is broad: paper for printing and writing, newsprint, magazine papers, tissue and toweling, cartons and boxes, building papers.

Wood is made up essentially of three organic chemical compounds: cellulose, hemicellulose, and lignin. As a fraction of the dry weight of wood, cellulose comprises

about 40-45 percent. Hemicellulose and lignin each make up 20-35 percent of the dry weight, depending on the species of wood, meaning that together these two compounds account for more than one-half of the mass of wood. As depicted in Figure 6, when making high quality printing, writing, and copying papers, wood is exposed to a cooking liquor, composed of strong chemicals that remove as much of the lignin and hemicellulose as possible. These compounds become an organic component of the cooking liquor that is now black. Cellulose is removed, cleaned, bleached, and used in papermaking. Recycled fiber, coming from a separate processing sequence, is also added prior to sheet formation. The finished paper product is largely cellulose, a bit of binder (such as starch), and fillers and perhaps a coating to provide a smooth or glossy surface. The hemicelluloses and lignin, on the other hand, are recovered and used to generate energy, a primary reason why paper mills nationwide are 50 to 70 percent energy self-sufficient. The original chemicals making up the cooking liquor are recovered as well for reuse in subsequent papermaking. A typical mill could be described as a place that produces two products: paper and energy for local consumption.

Figure 6
A Schematic of a Typical U.S. Paper Mill Operation



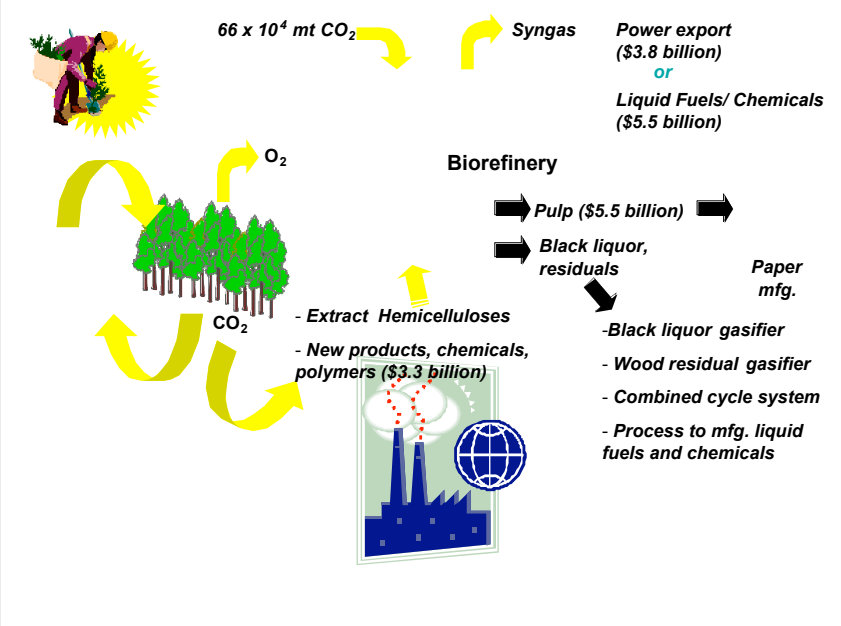
Source: Adapted from B. A. Thorp, 2004.

In the Future, Paper will be Only One of Many Products

The paper mill of the future will look much different than those of today. Instead of removing the hemicelluloses and lignin during the pulping process, the hemicelluloses will be extracted from pulp chips prior to subsequent processing, with these used to produce a variety of chemicals and polymers. Then, in the bio-refinery, the potential will

exist for conversion of wood to syngas[1], liquid fuels, pulp, and a wide array of industrial chemicals and chemicals and feedstocks; in effect, pulp (and paper) will become but one of many product options for the bio-refinery manager. In the process of conversion from paper mills to full bio-refineries, wood processing facilities will switch from net emitters of carbon dioxide (traceable to use of fossil-based fuels for a portion of process energy), to facilities that sequester substantial quantities of carbon through avoided emissions. Such facilities will also become more flexible, more responsive to the needs of society, and, potentially, much more profitable.

Figure 7
A Schematic of a Typical U.S. Paper Mill of the Future



Source: Adapted from B.A. Thorp, 2004.

The Bottom Line

Rapid change is occurring throughout industries of all kinds, and the paper manufacturing industry is no exception. Driven by a number of developments domestically and globally, the domestic paper industry is poised for significant change to a new, more diverse, more dynamic, and more profitable industry. Changes will occur as part of a larger national trend toward greater reliance on plants as a source of industrial chemicals and materials and energy – a trend increasingly referred to as the coming *Bio-revolution*.

Dr. Jim Bowyer is a professor within the University of Minnesota's Department of Bio-based Products (part time) and an Elected Fellow of the International Academy of Wood Science. He is the current Chairman of the Tropical Forest Foundation, Chairman of the Minnesota Bio-fiber Council, Scientific Advisor to the Temperate Forest Foundation and Past President of the Forest Products Society (93-94), and of the Society of Wood Science and Technology (87-88).

[1] Syngas consists primarily of carbon monoxide and hydrogen, is combustible, and about one-half the energy density of natural gas.

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