

Agenda

2020

**A Technology Vision
and Research Agenda
for America's Forest,
Wood and Paper
Industry**

November 1994

Background

This Technology Vision and Research Agenda was developed by the Chief Technical Officers of the forest, wood, pulp and paper industry, with advice from research institutions and other organizations. Guidance was provided by the industry leadership through a committee of Chief Executive Officers.

The Association Board of Directors, at their meeting on October 14, 1994, approved this document and authorized the work needed to develop an implementation plan for the Research Agenda in collaboration with agencies of the federal government and the major institutions with expertise in the field.

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GLOSSARY OF ACRONYMS

AF&PA	American Forest & Paper Association
DOE	United States Department of Energy
FPS	Forest Products Society
NCASI	National Council for Air & Stream Improvement
R&D	Research and Development
RPTA	Recycled Paperboard Technical Association
TAPPI	Technical Association of the Pulp and Paper Industry

AMERICA'S FOREST, WOOD AND PAPER INDUSTRY

LOOKING TO THE 21ST CENTURY: A TECHNOLOGY VISION AND RESEARCH AGENDA

EXECUTIVE SUMMARY

This document presents the forest, wood and paper industry's perspective of where the industry stands today, a desired state for the industry twenty-five years into the future, and the technology-related issues that must be addressed to accomplish the industry's vision of the future.

In many respects, this document represents a bold step forward for the industry. Never before has the industry with such unanimity taken a look at its future, the need for technological development, and ways to leverage its own capabilities with partnerships involving institutions, suppliers, and government.

Recognizing the inability of humans to accurately predict the future, the focus is on direction and broad, general goals rather than specific endpoints and solutions. Trying to predict the future with specificity always results in a presentation of the authors' biases and preconceived solutions to current problems. This report focuses, instead, on identifying major strengths and weaknesses of the industry and pressures from outside. Flexibility and multiple pathways towards the elements of the vision are believed to be essential, providing ability to adapt to a changing environment and unforeseen events.

Realizing that when we look ahead as far as the year 2020 our vision can hardly be 20/20, we must be prepared to re-evaluate our perspective periodically—perhaps every 3-5 years.

The Importance of the Industry to the Nation

The forest, wood and paper industry is a worldwide leader, globally competitive and an important contributor to the nation's economy. Employing 1.4 million people directly and producing products valued at more than \$200 billion per year, it ranks among the nation's top 10 manufacturing industries.

The wide array of products provided by this industry are safe, functional and, in many respects, essential to the everyday needs of citizens, government and other institutions. At home, paper products provide the bases for communications (through books, newspapers, notepaper and artwork), convenience and improved sanitary conditions (through paper towels, facial tissues, and disposables). Specialty papers provide protection to machines and to people through seals, gaskets, and filters. Paper and paperboard packaging materials protect and conserve all manner of products from production through distribution to end use.

After use, wood and paper products can be recovered for recycling, composting or conversion to energy. The industry has long been a leader in recovery and recycling. Paper is among the most intensively recycled materials in our society. Some 40% (or about 36 million tons per

year) of all the paper used in the U.S. is currently being recovered for recycling. The industry intends to increase this rate to 50% by the year 2000.

Trees provide the major raw material for this industry, necessitating a commitment to sustainable forestry. Recognizing the importance of this raw material base for long range survival, companies in the industry have a long standing reputation for being stewards of America's forests. Today, the U.S. has far more trees than in the 1920s and grows over one-third more wood than is used and lost to natural causes each year. Among the many favorable attributes of healthy, productive forests are: a favorable impact on the atmospheric carbon dioxide balance, preservation of soils, and protection of animal habitats. Wood also provides a source of clean, renewable energy.

Pressures on Performance and Competitiveness

In spite of the success of the forest, wood and paper industry, it has significant challenges ahead in meeting the changing standards of society while remaining economically viable and globally competitive.

The industry's most valuable asset, an abundant and low cost raw material base, is being challenged by developments both domestically and abroad. Land available for growing commercial wood is diminishing, and pressures are building to remove even more public lands from commercial production. In addition to driving up prices, this puts pressure on the industry to use lower quality wood which can in turn result in higher energy usage. For example, the reduced availability of large timber has shifted wood-based building materials towards engineered products which are more energy and capital intensive.

While recycling reduces the pressures on virgin fiber supply, further increases in recycling will require that lower grades of recovered fiber must be used, or this lower quality fiber must find uses in high quality finished products. Historically, most recycled fiber has been used in less demanding applications. Upgrading low quality recovered material is both costly and energy intensive.

The industry is also being increasingly challenged from abroad. In addition to traditional competitors such as Canada and the Scandinavian countries, which have always placed a high value on forest product exports, challenges are coming from new areas. With government subsidies, low-cost wood and cheap labor, countries such as Chile, Indonesia, Brazil, and South Africa are rapidly becoming the world's low cost producers. Technological leadership, once clearly owned by the U.S. industry, has also been shifted towards Canada and the Scandinavian countries over the past 20-30 years.

More demanding environmental requirements are also a major burden that the U.S. industry must bear over the next decade and beyond. To comply with a wide range of new regulatory initiatives, the industry is facing unprecedented increases in capital expenditures, operating costs and energy use.

The pulp and paper industry is the nation's most capital intensive manufacturing industry and is among the most energy intensive. Currently, the industry is 57% energy self sufficient; up from 36% in 1972—a substantial achievement. However, in spite of tremendous progress, long-term viability demands improvements in energy and capital efficiency if financial performance is to be enhanced and reach satisfactory levels.

The Industry's Vision for the Future – 2020

The U. S. forest, wood and paper industry will continue to be the global leader in providing safe and essential products based on forest resources. The industry must be financially healthy and attractive not only to the investment community but also to the communities in which it operates and the nation as a whole. It will be an example of sustainability with its renewable raw material growing in productive, well-managed forests at rates considerably greater than today. The virgin raw material base will be increasingly leveraged with material recovery and recycling.

Manufacturing plants will operate in harmony with the environment and the communities in which they are located. Water use will be low and discharges to the air and water will be closely controlled to minimize effects on the environment. Regulations will take into account environmental effects as well as energy use and economics.

More energy efficient processes will evolve and an even larger amount of the industry's energy will be self generated based on biomass and waste materials, with excess energy marketed in the form of electricity and liquid fuels.

Productivity will be substantially higher than today, and less costly processes will be developed, improving capital efficiency and leading to enhanced financial performance.

Highly skilled and motivated employees will operate the industry's automated manufacturing facilities. Worldwide technological leadership will be regained as the best scientists and engineers are attracted to the industry and cooperative pre-competitive efforts between the industry, universities, and government flourish.

The Long-Range Research Agenda

Comparing the vision of the future with the current state of the industry leads to a number of research needs. This technology vision and research agenda discusses those needs that will advance the entire industry and are also suitable for cooperative research efforts. High priority efforts will include the areas of:

- Sustainable Forest Management
- Environmental Performance
- Energy Performance
- Improved Capital Effectiveness
- Recycling
- Sensors and Control

Each of these research areas is relevant to all three industry segments—forestry, wood products, and pulp and paper products. This research agenda also covers a spectrum of program maturities, from basic research to development and demonstration projects.

Specific product research and development areas are not addressed in this agenda. Although product development is essential to the long term success of the industry, it is a primary basis for competition among companies and is best left to the individual efforts of company proprietary research and development programs. However, studies of the fundamental

chemical and physical characteristics of fibers and fiber structures are included. Individual company researchers and product developers should use the results of this fundamental research to advance proprietary product development and to promote competition.

The Need for a Cooperative Research Program

America's forest, wood and paper industry is facing rapidly accelerating worldwide competition. In addition, complexity is increasing due to changing societal values and interaction of many competing pressures. Many of the research needs facing the industry today are industry-wide and too costly and complex to be handled by individual companies alone. Global competition has forced rationalizing of the industry's long-range, generic research capabilities, making scarce resources too valuable to be wasted with duplication of efforts. Now is the time for the industry to partner with government, suppliers, national laboratories and universities to leverage all available resources. Successful efforts to address the major technological issues discussed in this document will ensure the continued success of one of America's most important basic industries.

Developed by the industry's Chief Technology Officers
under the guidance of a Chief Executive Officers Working
Group for the American Forest & Paper Association

Date: September 26, 1994

AMERICA'S FOREST, WOOD AND PAPER INDUSTRY

LOOKING TO THE 21ST CENTURY: A TECHNOLOGY VISION AND RESEARCH AGENDA

1. INTRODUCTION

The U.S. forest, wood and paper industry represents one of the country's greatest assets. The industry is globally competitive and attractive from the standpoint of sustainability and environmental compatibility. In many ways this industry is an ideal example of a desirable, self-sustaining industry which should be supported by the nation. In addition to generating hundreds of thousands of productive, well-paying jobs and creating wealth shared by many, the industry:

- produces safe, essential products that contribute to improved quality of life and efficiency of government and business;
- is based on a renewable and sustainable raw material;
- produces products which are recycled, composted, converted to energy and are bio-degradable;
- achieves substantial levels of recovery and recycling;
- is based on integrated energy production from residual materials and is a positive contributor to the nation's renewable energy goals;
- contributes favorably to the global carbon balance;
- contributes to forest health through land management, reforestation and conservation of habitats;
- provides sporting opportunities and recreational areas for the public; and
- employs manufacturing processes which use extensive recovery, recycling and pollution prevention methods.

In spite of these desirable characteristics, the industry faces significant challenges ahead in meeting the changing standards of society while remaining economically viable and globally competitive. The industry has and will continue to undergo change over time. Its high capital intensity and the resulting economic consequences of equipment replacement tend to limit experimentation, development and application of large, new core technologies, particularly in the pulp and paper segment. In a rapidly changing environment with increasing social, regulatory and consumer expectations, it is imperative to encourage technological innovation to meet these challenges. At times, these changing expectations exceed the industry's capability to respond and, therefore, require broader collaboration among all stakeholders.

This document provides an overview of the major technology options needed to accomplish the industry's vision. By addressing the needs identified below—through a partnership with government, the industry's stakeholders, public and supporting laboratories and institutions—the continued success of one of America's most essential and desirable industries can be assured.

2. BACKGROUND

The federal government has been investing in the competitiveness of American industry for many years. The forest, wood, and paper industry has participated in this funding to a lesser extent than other industries (notably textiles, automotive, and semi-conductors).

During the past year, the U.S. Department of Energy has been encouraging the industry to develop an industry-supported vision for the future which could be used to better direct government investments in R&D to important industry needs. The DOE is also encouraging the industry to develop a coordinated effort to take advantage of, where appropriate, the \$10 billion a year currently being invested by the federal government on industrial research.

The AF&PA, supported by NCASI, RPTA, FPS, and TAPPI, has been identifying the major long-term technological needs and challenges that could have significant impact on the industry 20–30 years in the future. Since perfect vision into the future is impossible, this document should be reviewed and updated regularly, perhaps every 3–5 years. It is hoped that the information assembled here will be useful to: (1) advance the fundamental research needs of the industry; (2) provide a basis for allowing individual companies to become more globally competitive; (3) assist the industry and government funding agencies in allocating research funds to the most important research needs; and (4) serve as a basis for communication with government agencies to expand government/industry partnerships.

The process of developing the industry's technology vision and research agenda has been led by a CEO level working group headed by the Chairman of AF&PA and composed of CEOs representing the full range of industry products and interests. Drawing on earlier work by the AF&PA Energy Council, the CEO group empaneled and guided the efforts of a broad-based Chief Technology Officers' working group to expeditiously refine and finalize an industry research agenda. The input from over thirty institutions supporting industry research was obtained at a workshop held in August (see Appendix). In early September, the CEO leadership group approved the document for discussions with the DOE and for presentation to the AF&PA Board of Directors.

3. THE FOREST, WOOD AND PAPER INDUSTRY TODAY

A. Industry Overview

The American Forest & Paper Association is the national trade association of the forest, pulp, paper, paperboard, and wood products industry. AF&PA represents approximately 425 member companies and related trade associations (whose memberships are in the thousands) which grow, harvest, and process wood and wood fiber; manufacture pulp, paper, and paperboard products from both virgin and recovered fiber; and produce solid wood products. As a single national trade association, AF&PA represents a vital national industry which accounts for over 7% of the U.S. manufacturing output. Its members account for more than 90% of the domestic paper and recycled paper manufacturing capacity.

For more than three centuries, the forest, wood and paper industry has made a vital contribution to the realization of the American dream. The industry has framed houses,

finished offices, built containers, packaged goods, spanned rivers, held rails straight, carried news, provided sanitary products; it has provided products for great corporations and small businesses, picnics and political rallies and produced paper for magazines and newspapers, novels and encyclopedias, poetry and art. Generations have been entertained with jigsaw puzzles, paper airplanes, paper dolls and ice cream sticks.

The industry has employed countless millions of working men and women in thousands of mill communities across the nation, bringing growth and vitality to local communities, creating a dependable tax base to build schools and roads and theaters, and public works of every description.

Above all, the forest, wood and paper industry has tried to keep the forest in perspective, not only as an essential basis for industry, but as the handiwork of nature's life cycle, constantly renewing and replenishing itself for the multiple uses of man and wildlife.

Today, the forest, wood and paper industry produces wood and paper products valued at more than \$200 billion each year with contributors ranging from large, state-of-the-art mills to small family-owned sawmills and some 7 million individual woodlot owners.

It employs 1.4 million people directly and ranks as one of the top 10 manufacturing industries in 46 out of 50 states.

B. Forestry

A healthy and productive forest is essential for the forest, wood, and paper industry. Today, the U.S. has far more trees than in the 1920s and grows over one-third more wood than is used and lost to natural causes each year.

In 1993, 1.7 billion seedlings were planted in the U.S.; 43% were planted by forest products companies which own only 14% of the U.S. commercial timberlands. An acre of young, healthy, growing trees is capable of producing in excess of 4,000 pounds of wood in one year. These trees consume nearly 6,000 pounds of carbon dioxide during their growth, thereby sequestering carbon for long periods of time.

The industry's future depends on practicing responsible forest management principles for sustainable development to provide for both protection and efficient use of the nation's forests.

C. Wood Products

Wood products occupy a unique position in North American society. Because of its versatility, wood has been used extensively as an industrial material throughout the history and settlement of the continent.

Over 95% of all homes in the U.S. are built with wood-framed walls and roofs. Because wood is a sustainable, energy-efficient building material and is renewable, it is the basis for economic housing. The per capita consumption of wood in the U.S. increased over 30% from 1970 to 1987.

Expanding population and development creates much greater demand for energy conservation. Wood products are preferred over other materials because of low embodied energy and low thermal conductivity. Solid wood is 4 times more efficient as an insulator than cinder block, 6 times more efficient than brick, 15 times more efficient than concrete,

and 1,770 times more efficient than aluminum. From raw material to the finished final product, steel studs take 9 times more energy to produce and transport than wood studs; aluminum siding takes 4 times more energy to produce and brick veneer 22 times more energy than wood siding; concrete floors take 21 times more energy to produce than wood floors.

Wood is effective in harsh conditions. Flexible frames “give” during earthquakes, preventing cracking and crumbling. Most of the wood-frame homes survived the 1994 Northridge, California earthquake with little more than cosmetic damage, and wood-frame structures built-to-code also survived Hurricane Andrew’s winds.

To meet changing marketplace needs, wood-based products are being combined with other materials to produce advanced material composite products that have optimized characteristics.

D. Pulp and Paper Products

Diversity and change are inherent in the pulp and paper industry. The industry is characterized by both large high speed mills and by many small specialty mills. It is very significant on an international scale. Exports include wood pulp, kraft linerboard, and wastepaper. Major imports include wood pulp, newsprint, and printing and writing paper.

There are many facts and figures that underscore the breadth of the pulp and paper industry in the U.S. The pulp and paper industry includes 547 mills in 42 states, and produces 82 million tons of paper and paperboard and 10 million tons of market pulp. With only 16% of the world’s pulp mills, the U.S. produces 35% of the world’s pulp. Paper and paperboard are used to publish more than 2 billion books, 350 million magazines, and 24 billion newspapers in the U.S. annually. The U.S. mill output equals that of the next four top countries combined.

From an investment perspective, more than \$120,000 of plant and equipment is invested on average for every industry employee, which is more than twice the average of other domestic manufacturing industries. U.S. companies have invested more than \$100 billion since 1980 to raise productivity, quality, and underwrite expansion into new products and markets.

America’s papermakers are fully committed to their paper recovery goal. A full two years ahead of schedule, the industry has reached its goal of recovery for recycling and reuse of 40% of all paper Americans use (that’s 36 million tons) and has set a new goal of 50% recovery by the year 2000. There are about 550 facilities in the U.S. making paper, paperboard and building products. More than 400 of these facilities use recovered paper as a raw material for papermaking. More than 200 rely on it entirely. By the year 2000, expenditures aimed at increasing the industry’s paper recycling capacity will have exceeded \$17 billion over a twenty-year time period.

The industry has an impressive track record in the environmental and energy fields. It has reduced the amount of water used to produce each ton of paper by 70% over the past two decades and is significantly ahead of schedule meeting emissions reduction goals developed by the EPA. The industry voluntarily reduced dioxin discharges by 92% over the past five years, so that dioxin levels now cannot be measured in the wastewater of every nine out of ten bleached pulp mills, and 100% of mills will have undetectable amounts by 1996.

Industry spending for environmental improvement exceeds \$1.0 billion per year, which currently is an estimated 20% of capital spending—a percentage which is anticipated to increase dramatically by the end of this century.

The industry each year consumes approximately 3 quads of energy to make its products and has made significant progress in both energy use and self sufficiency over the last 20 years—currently operating at 57% self sufficiency, up from 36% in 1972. In spite of the above statistics, the industry is still the fourth largest user of fossil fuels in the industrial sector.

E. Global Competitiveness Issues

The U.S. forest, wood and paper industry is currently ranked as one of the most competitive in the world, exporting over \$17 billion worth of products in 1993. With the 1993 implementation of the North American Free Trade Agreement (NAFTA) and agreement in the Uruguay Round of multilateral trade negotiations (GATT) to reduce or eliminate tariffs by 2005, long-term prospects for U.S. exports of wood and paper products should improve markedly. However, to realize its full potential, the U.S. industry must remain competitive in raw material supply, compete effectively with the threat of new materials, operate in harmony with the environment, and strengthen its image as a good investment with its stake holders and as a good corporate citizen with the public.

Consider these statistics that reflect both the global competitiveness opportunities and threats to this industry:

- U.S. wood products valued at \$7.3 billion were exported in 1993, \$2.3 billion of which was softwood and hardwood lumber. Because of tightened lumber supply in the Pacific Northwest and fewer overseas log exports, imports valued at \$8.3 billion surpassed exports.
- Exports of U.S. pulp and paper products were also considerable in 1993, totaling \$9.6 billion. The relatively strong economic growth in the U.S., coupled with recessions in major industrialized countries, created a surge of paper and paperboard imports into the country. U.S. pulp and paper imports were valued at \$10.6 billion.
- The largest wood products export markets for the U.S. in 1993 were Japan (\$3.2 billion), European Union (\$1.2 billion) and Mexico (\$474 million). For pulp, paper and paperboard products, the biggest export markets were Canada (\$2.1 billion), European Union (\$1.7 billion), and Mexico (\$1.4 billion).

Developing countries (e.g., Chile, Indonesia, and South Africa) are now setting the pace as low cost producers of pulp and some paper products; this is due to their low cost of labor and wood, and subsidies from their governments. Other lesser developed countries with abundant wood resources will likely join these challengers. Also Canada and the Scandinavian countries have traditionally been strong competitors in the forest products industry. Because of the high dependence of their national economies on forest products, they will undoubtedly continue to press the U.S. producers with high quality, low cost products, and technological developments.

In the 60's, the U.S. was the clear technical leader in pulp and paper science, processes and equipment manufacture. However, in the 90's the Scandinavian countries and Canada have taken the lead in many areas, presenting a challenge in the next decade to regain the U.S. leadership position.

The tremendous capital investment required during the 1980s to build and maintain the industry's global competitiveness, coupled with increasingly large environmental expenditures, has taken a heavy toll on industry cash flow, and increased debt to historically high levels. The prospect of additional scarce industry capital being invested to meet marginally beneficial but costly environmental requirements further threatens the industry's global competitiveness.

4. THE VISION FOR THE FUTURE

A. Forest, Wood and Paper Industry Overview

The U.S. forest, wood, and paper industry in 2020 will be the clear global leader in providing safe and essential products in harmony with the environment and will be a sustainable contributor to our nation's economy and to the quality of life of its citizens.

Issues related to **sustainability** and to **energy performance** will play a much more prominent role than today. Expanding global population and development will create much greater demands for energy, resulting in heightened recognition of the need for greater **energy conservation**. Raw materials for both durable and non-durable products will be evaluated based on **sustainability analyses**.

Construction materials, increasingly in demand to meet growing world-wide development, will be evaluated and specified for use based on their own energy demands in production and energy conservation performance when in place. Wood-based products will be preferred over other materials because of low embodied energy and wood's renewability as a raw material. The nature of forest resources with respect to watershed stabilization, ground water quality, habitat diversity, soil conservation, and atmospheric carbon dioxide balance help place all products derived from wood in a favored position.

There will be an increased awareness of the total impact of the industry from **sustainable silviculture** to final product disposal. Process changes will continue to be evaluated from a life cycle perspective to ensure an understanding of the total impact of recommended changes. Increasingly, the industry will come to be viewed as fundamentally in harmony with the environment by managing renewable resources to provide useful products, as well as energy, for society. The use of recovered materials not suitable for product use will also be an accepted energy source for conversion in clean waste-to-energy facilities. Recovered materials will be viewed as a resource and effective systems will be in place to minimize material flows to landfills.

Enhanced financial performance nurtured by **improved capital effectiveness** and a broader range of products will make the industry less cyclical and more viable long term. This will allow smaller increments of capacity to be brought on line in response to demand and give the industry more flexibility in installing new technology.

Recycling of wood and paper products will play a much more prominent role as cost-effective collection and processing technologies are developed. Source identification

and enhancement, collection, and reuse will heighten the recovery rate, increasing the industry's product content of once lost recyclable fibers and wood residuals. This will result in an increase in the available resource to meet the greater demand for wood products. Under-utilized species will become an important source of raw materials as technology is developed to improve harvesting and produce economical products from them.

B. Forest Resources

By 2020 there will be an increased awareness of the potential for optimizing the substantial forested land assets of the industry as well as strengthened partnerships between industry, government and other private land owners. Recognition for responsible stewardship of public and private lands will have been achieved which integrates the growing, nurturing and harvesting of trees for useful products with the conservation of soil, air and water quality, wildlife and fish habitat and aesthetics. Biomass will be used not only for building materials and paper and paperboard products, but also increasingly for steam, power, and liquid fuel production.

Although trees as a fiber resource are expected to continue to dominate, recycled fiber will be a larger proportion of the raw material supply than today. Residuals from forests, mills, and converting plants as well as non-recyclable recovered paper, and possibly wood grown specifically as fuel, will provide an important renewable fuel resource.

Wood grown as a raw material for the forest products industry is expected to receive major attention over the next several decades. **Genetic technology and other forest science advances** (e.g., gene identification and modification) are expected to enable the growing and harvesting of substantially increased quantities of wood from available land resources, potentially more than doubling current yields per acre. With proper research, domestic supplies will be enhanced through a combination of improved genetic selection, bio-engineering, use of marginal agricultural lands for tree production, and forest management. These developments will ensure that the industry remains competitive with other low-cost producing regions of the world.

New technology and practices will have substantially reduced the current impact of **harvesting methods** on forested lands while reducing costs of moving the industry's raw material from the standing tree to its manufacturing facilities.

Based on better understanding of the **properties of wood** and its components and how to use them most efficiently (including an update of the Committee on Renewable Resources for Industrial Materials—CORRIM—report), a plethora of new and improved wood-based products will be developed. While the competition from other technologies such as electronic communications and a possible trend towards lower per capita consumption of forest based products in developed countries may have tended to reduce wood products usage, growth in lesser developed areas and the advantages of renewability and sustainability compared to other materials are expected to increase the total demand for forest, wood, and paper products.

C. Wood Products

Wood products will be valued for their contribution to the nation's livelihood and well-being. Because they are economical and made from a sustainable resource, they will have a favored position relative to products made from non-renewable raw materials. New products and processes for producing them will be strikingly evident compared to the 1990's.

Processing techniques for wood products will be compatible with the range of available resources, including genetically improved strains, and will be used to produce high value products. Log sorting will be done with nondestructive evaluation techniques for optimum use in end products with closely controlled properties. Automated processing systems will have been developed to accurately locate high value material and optimize the yield for structural products. Perhaps most importantly, new wood products, unlike those currently available, will be manufactured to meet a changing marketplace. Building design will emphasize a systems approach, rather than specification of individual building elements. This evolution will favor the flexibility of wood-fiber based products. New products will have high built-in levels of reliability allowing their substitution in uses not presently permitted. Wood-based products will be combined with other materials to produce "advanced material" composite products that have optimized characteristics, taking advantage of the best features of the combined materials. Treatment technologies will increase wood product service life.

The view for the future includes development of high technology processes with highly automated equipment operated by skilled and trained workers in safe and comfortable environments. Education and training of operators, as well as scientists and engineers, will be of increasing importance.

D. Pulp and Paper

Because of their utility, functionality and attractiveness as well as the recognized sustainability of the raw material supply, new and improved pulp and paper products will continue to be widely used in our society. The major virgin raw material for paper will still be wood. Recovered fiber will have a much greater role than it does today—achieving 50% recovery, of which the majority will be used as raw material going into finished products. Alternative plant fiber will be increasingly viewed as a component of fiber supply but will remain small overall.

A refined and improved collection system for recyclable fibers will develop with public education, community, government, and business initiatives and support. This growth of supply will permit the continued increase of recycled content in products of the future and allow for maximum effectiveness of material recovery and solid waste management programs.

Wood pulping will continue to be dominated by chemical processes, but there will be an increasing improvement in the environmental compatibility of pulping and bleaching operations. In accomplishing these changes, a reduction in the **capital cost** of new pulping facilities and equipment will also have been achieved. The dominant pulping technology is still expected to be the kraft chemical process, but there will be a trend toward increased use of processes that do not utilize reduced sulfur compounds. The chemical recovery of black liquor from the kraft process is anticipated to progress toward

gasification technologies and other processes that have the potential for more optimized cogeneration of the required process electricity and steam. It is also anticipated that these technologies will lower the high capital cost currently associated with the recovery process. The Tomlinson recovery furnace will still be in use, but will be phased out as new facilities come on line and new technologies are introduced. However, advances in design and control will make the Tomlinson units safer and more efficient, and will further improve environmental compatibility. New bleach plants will result in **improved environmental compatibility** through the use of technologies such as reduced water usage, extended use of oxygen based chemicals, and other alternatives. Many of the limitations of mechanical pulping processes (high energy intensity, discoloration with age and reduced strength properties) may be resolved allowing for a greater fraction of paper products to be produced from these high-yield pulps.

It is expected that papermaking processes will also be less capital intensive and will require less energy and fresh water supply. One of the more capital and energy intensive operations in the papermaking process is water removal. Advances are anticipated in the **forming, pressing, and drying** of pulp slurries which will result in improved quality, reduced capital costs, and reduced energy intensity. Paper products will be manufactured to meet ever more stringent consumer quality requirements, and new products will be introduced more quickly to satisfy changing consumer needs. Advanced **process sensors**, computer control systems, expert systems, and mill information systems will continue to be developed and implemented throughout the mill to aid in meeting the product quality requirements as well as to assist in the efficient operation of the manufacturing plant. **Computer-based control systems** will extend into the distribution and logistics networks to reduce inventories and shorten product delivery cycles.

Improved understanding of the **fundamental chemical and physical properties of fibers**, fiber structures and their interaction with other materials applied in or after the papermaking process will assist in designing better products. New products, whether those made from paper alone or in combination with other materials, will be more functional while using less energy and materials.

Energy consumption per unit of product output will be lower; however, electricity will be an increasingly important fraction of the energy used. **Biomass and black liquor gasification** will play an increasingly important role as components of advanced cogeneration technologies. These technologies will be incorporated to optimize the generation of electricity and process heat. Compliance with air regulations will necessitate effective combustion control and accurate continuous monitoring. There will be a trend toward closing the remaining open water cycles in mills and the goal for all mills will be to continue to **reduce water consumption**.

The capital cost of facility rebuilds and expansions as well as new construction will be reduced out of necessity. Technologies involving new processes, **new materials of construction** and **new construction techniques** will be employed to lower forest, wood, and paper industry capital intensity, bringing it closer to the all-industry average.

With the continual tightening of pulp and papermaking processes will come the need for improved or alternative materials of construction or ways to handle the changing chemistry of the process. To ensure safe operating systems with high levels of integrity, corrosion and materials management must be well understood.

As with the wood products segment of the industry, the future includes the development of high technology processes with highly automated, modern equipment which is operated by skilled and trained workers in safe and comfortable environments. Thus, education and training of operators as well as scientists and engineers will be imperative.

5. TECHNOLOGY SUMMARY

In comparing the forest, wood and paper industry's vision of the future with today's situation, several important strategic issues emerge which drive the proposed technology program to:

- become more competitive with developing countries in wood and fiber production;
- anticipate and understand public expectations associated with its woodlands and manufacturing operations;
- establish a position of increased energy efficiency;
- improve capital effectiveness;
- enable the collection and use of materials generated by non-traditional sources of recovered fiber;
- increase product flexibility and reduce cycle time for new product introduction; and
- maintain leading-edge, low-cost manufacturing facilities for producing high quality products.

6. RESEARCH PRIORITIES

AF&PA, supported by NCASI, RPTA, FPS and TAPPI, has made a concerted effort to develop a long range research agenda for the industry. This effort has involved representatives from the pulp, paper, packaging, recycling, forestry and wood products segments of the industry. It is the intent of this research agenda to set a direction for the entire industry as opposed to any single segment or company. This is consistent with the primary goal of improving the global competitiveness of the industry as a whole. Further, the agenda as presented here, focuses on raw material, environmental, energy and process areas and not on product research areas which are deemed to be more appropriately carried out by individual companies as they see fit. However, the agenda does emphasize an improved understanding of the fundamental science and technology, such that individual company product and process developers can use the anticipated research results to help their company's products not only excel in performance against other materials, but also to maintain healthy intra-industry competition.

Importantly, the implementation of this agenda must be a cooperative effort between government funding agencies that can help accelerate the needed research results and technology commercialization, the research institutions that support the industry, suppliers to the industry, and the industry itself. To this end, the supporting institutions have been involved in the development of this document. Government agencies will find its contents useful in considering policy affecting the industry and in making funding decisions.

The analysis undertaken has led to several high priority areas for research, development, and commercialization. These are summarized below.

A. Sustainable Forest Management

The industry needs to continue its practice of sustainable forestry which integrates the production of wood and paper products with other environmental values including the conservation of soil, air and water quality, wildlife and fish habitat, and aesthetics. On industry's most productive sites, growth rates must increase and fiber quality will need to be substantially enhanced (perhaps 2-4 times current growth rates) to continuously improve the industry's competitive advantage in wood production, harvest and delivery to world markets. Forested areas on marginal agricultural lands will be increased and will need specific attention.

In 1993, AF&PA published a detailed national report outlining the Industry's Suggested Forestry Research Priorities for the 1990's. In addition, the National Research Council of the National Academy of Sciences published a report: *Forestry Research, A Mandate for Change* to serve as a vision for future forestry research.

Common areas of high priority research include:

- *Sustainable Forestry* – Develop systems and methods to sustain the productivity of intensively managed forests for present as well as future generations, including attention to biodiversity.
- *Selection and Hybridization* – Develop optimum natural species and hybrids for use in local conditions.
- *Genetic Engineering and Tree Breeding* – Modification of gene structure and incorporation in improved tree breeding and genetic selection programs to increase growth rates, improve insect and disease resistance, improve fiber quality, and enhance environmental adaptability.
- *Forest Management and Productivity* – Develop and implement management techniques to maximize fiber yields at low cost and to minimize ecological impact, including conservation of certain unique ecosystems.
- *Raw Material Properties* – Given the shift towards a greater reliance on younger, faster grown material, a concentrated effort is needed in the areas of: 1) tree physiology, plant genetics, and the integration of genetics with silviculture to achieve fast-growing, disease-resistant, good form trees that produce high quality wood; and 2) fundamental information that will allow the use of short rotation trees and mixtures of traditional and non-traditional species in a wide range of solid and composite wood products and as a wood pulp raw material.
- *Harvesting* – Develop low-cost and energy-efficient harvesting techniques that have low impact on the productivity of soils and allow for selective cutting.
- *Soils* – Enhance the level of knowledge and develop approaches to protect the basic productivity of soils.
- *Diversity* – Develop methods to ensure adequate preservation of gene pools and local diversity of species.

- *Forest Inventory* – Improve information collection regarding quantity and quality of timber, age class distributions, and the effects of expanding markets on overall supply.
- *Water Quality* – Identify compatible forest practices with other wetland functions, water quality and quantity and beneficial uses of riparian areas.
- *Ecosystem and Landscape Planning* – Develop models and other analytical tools for assessing effects of various landscape patterns and how forestry can help maintain resource values over time and space.

B. Environmental Performance

The industry must continue to assure that manufacturing facilities are worker and community acceptable. Research on understanding the effects of potential discharges should receive priority. Some specific areas for continued and future consideration include:

- *Human and Environmental Effects* – Study effects of manufacturing process discharges on humans and the environment.
- *Energy and Environmental Trade-offs* – Recognize, before broad implementation, the environmental and energy impacts of technology changes directed at improving environmental performance.
- *Improved Wood Products Adhesives* – As new products are developed, the use of adhesives will increase. Research is needed to ensure they are durable, low-cost, and produce no toxic side effects on workers and users.
- *New Treatments for Durability of Wood Products* – The service life of wood in exposed environments can be extended significantly by designs and treatments to control fire, decay, mold, insect infestation, etc. Concerns have been raised with current treatments about the environment, human safety, recyclability and disposability. Research to develop benign treatments that can enhance the durability of wood products and improve dimensional stability is needed.
- *Reduction of the Impacts of Liquid Effluent* – Develop technology for enabling wood products, pulp and paper mills to operate in harmony with the environment.
- *Reduction of the Impacts of Gaseous Discharges* – Develop low odor pulping, efficient capture and treatment of gases, and low emission process technologies for the manufacture of wood, pulp, paper and recycled products.
- *Solid Wastes* – Develop waste minimization, recycling, and energy recovery strategies and technology.
- *Removal of Non-Process Elements in Pulp and Paper Operations* – Develop low cost, energy efficient separation technologies to remove contaminants, and treatment technologies to clean remaining discharges.

C. Energy Performance

To be economically competitive, the industry must be able to utilize the lowest cost fuel at all times and capitalize on emerging low cost technologies. Where economics are favorable, it is possible for many operations within the industry to become essentially independent of fossil fuels, meeting their internal needs with self-generated, renewable fuel from what are now waste streams. In addition, as the nation's demand for electricity and renewable liquid fuels increases, the industry can be an effective partner with utilities, chemical, and oil companies in helping achieve renewable energy goals. To accomplish these goals, energy utilization and production technologies must be improved as well as the development of new techniques to extract maximum energy from the waste streams. A partial list of areas needing attention are:

- *Energy Conservation* – Studies in this area should include methods of low level heat recovery.
- *“Life Cycle Assessment” of Materials and Systems* – Forest, wood and paper products need to be carefully evaluated relative to their energy efficiency in production and use compared to other materials.
- *Energy Efficiency in Wood and Paper Drying* – Wood drying is the largest energy requirement in the production of wood products. Improved understanding of the fundamental relationships between drying efficiency and product quality and uniformity is needed for both wood and paper products.
- *Combined Cycle, Cogeneration* – This area should address the goal of extracting maximum usable energy from biomass, waste and fossil fuels and the development of productive uses for the non-combustible products.
- *Biomass and Black Liquor Gasification* – These technologies should be commercialized to allow improvement in efficiency and reduction of capital intensity.
- *Non-Recycled Wood and Paper to Energy* – Develop collection and conversion technologies to take maximum advantage of the high value wood and fiber components diverting the remaining residuals to energy production in an environmentally acceptable manner.
- *Wood Based Chemicals* – Opportunities for process integration allowing the production of chemicals should be continuously evaluated as new technologies are developed and competing economics change.

D. Improved Capital Effectiveness

Reducing capital requirements per unit of production and sales will enhance financial performance and make the industry more viable by allowing smaller increments of capacity to be brought on-line in response to demand and by giving the industry more flexibility in installing new technology. All R&D areas should address the capital intensity issue as well as their primary objectives.

- *Kraft Chemical Recovery Process* – Develop lower cost, safer and more efficient alternatives to the existing processes. Black liquor gasification has significant potential.

- *Water Removal* – Develop lower cost, more energy efficient forming, pressing and drying technologies for paper and wood products.
- *Construction Methods* – Develop methods for constructing large and small facilities at lower cost.
- *Materials for Fabrication* – Develop new materials for the industry's processing equipment which are cheaper to use, less expensive to maintain, and stand up to the harsh nature of the many chemical process technologies utilized. All through the pulp and papermaking process (e.g., recovery furnaces, bleach plants, paper machines, chemical preparation and storage) better materials are needed to withstand the severe heat, physical, and chemical environments. Also, more rugged and durable materials are needed for the construction of harvesting and log processing equipment, which is subject to extreme mechanical stress.

E. Recycling

Recycling broadens the raw material base of both the wood and paper products industries. Enhanced development of the “urban forests” will continue to be investigated by organizations such as RPTA, who work with equipment manufacturers and the industry to achieve favorable separation and recovery of fibers. Once separated, these fibers can be successfully incorporated in a wide variety of pulp, paper and other products. Optimal combination of the virgin and recycled pulps is highly complex and should receive attention. R&D aimed at lower cost, reducing energy usage and fiber deterioration in recycling is key to significantly expanding the use of recycled products. Some additional specific areas for research, development and commercialization are:

- *Collection Systems* – Innovative collection techniques, systems and equipment are needed to significantly improve the acceptance and economics of moving more recovered materials into products that require increasing performance and quality.
- *Separation Technologies* – New cleaning system technologies are needed to allow for more specific separations between desirable recycled components and unacceptable contaminants, thereby increasing the amount of recycled fiber useable in marketable products.
- *Fundamental Understanding of Fiber-Fiber Bonding* – Improved product strength together with increased recycled fiber use can be achieved by a better understanding of fiber surface chemistry.
- *New Technologies for Sludge Use and Disposal* – Emphasis here should be on methods to allow deinking plants to operate in a more environmentally acceptable and economic manner.
- *Methodologies and Tools* – Techniques are needed to allow the establishment of valid statistical characterization of incoming recycled fiber raw material streams.
- *Concepts and Technologies for Wood Recycling* – Systems for wood recycling need to be developed that are cost efficient and environmentally acceptable. Development of such systems needs to include recycle capabilities for much of the construction and demolition waste currently going to landfills, as well as composite materials containing varying resins and chemical treatments.

F. Sensors and Control

- *Process Measurements and Controls* – The complexity of processes and the need for maximum efficiency and low cost require the need for ever-increasingly sophisticated real-time measurement and control systems. Some specific areas for consideration:
 - *Environmental-related Sensors*, internal and external
 - *Process-related Sensors*
 - *Product Quality Sensors*
 - *Large System Controls* to optimize and control entire mills or larger systems
 - *Expert Systems*
- *Wood, Fiber and Paper Products Characteristics* – Knowing more about the fundamentals of structural, optical and other performance attributes will lead to higher product performance which can either reduce the amount of material needed to obtain necessary performance or allow design of unique qualities into products so they can compete more favorably with other materials.
- *Computer-based Models of Wood Characteristics and Structural Performance* – Development of cost-saving computer-based models are needed that can demonstrate the structural and fire performance characteristics of wood products and systems, enhance innovation in design, reduce costly destructive testing, and provide confirmation of acceptable performance.

7. CLOSING COMMENTS AND NEXT STEPS

The U.S. forest, wood and paper industry has been very successful in maintaining a low cost, high performance position in the global arena over a number of decades. However, it is rapidly being challenged not only by the traditional competitors (Canada, Scandinavia, Japan) but also by some aggressive emerging nations (Brazil, Chile, Indonesia). Other third-world countries with abundant wood resources are expected to enter the global picture within the next 10–12 years. The U.S. forest, wood and paper industry and its stake holders cannot allow this new era of global competition to diminish in any way the industry's future success and growth opportunity. The jobs, exports, infrastructure, assets and opportunity for the creation of wealth that the industry represents must be protected and nurtured. Because of significant demands for capital to meet mandated environmental objectives, industry's research and development investments do not fully address the longer-term needs of the industry. U.S. wood products, pulp and paper companies are currently not spending enough on R&D to remain competitive over the long term against other industries or against European and Scandinavian manufacturers. Thus, the industry welcomes initiatives to strengthen the partnership between government agencies (e.g. the DOE, USDA, Department of Commerce) and industry to ensure that this prominent sector of our economy continues and expands as a viable industry in this country. With early attention to the high priority needs described above, this important industry will continue to maintain its competitive advantage in the global market place.

Following approval of this technology vision and research agenda by the AF&PA Board of Directors, an implementation plan will be developed in partnership with DOE and other interested government agencies, a team of CEO's, Technology Officers, and other appropriate individuals. The plan should include, but not necessarily be limited to:

- an operating structure;
- a framework for partnership; and
- a blueprint for the implementation program and evaluation of results.

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