

BIO-BASED PRODUCTS
MAINE FUTURE FOREST ECONOMY PROJECT



**CURRENT CONDITIONS AND FACTORS INFLUENCING THE
FUTURE OF MAINE'S FOREST PRODUCTS INDUSTRY**

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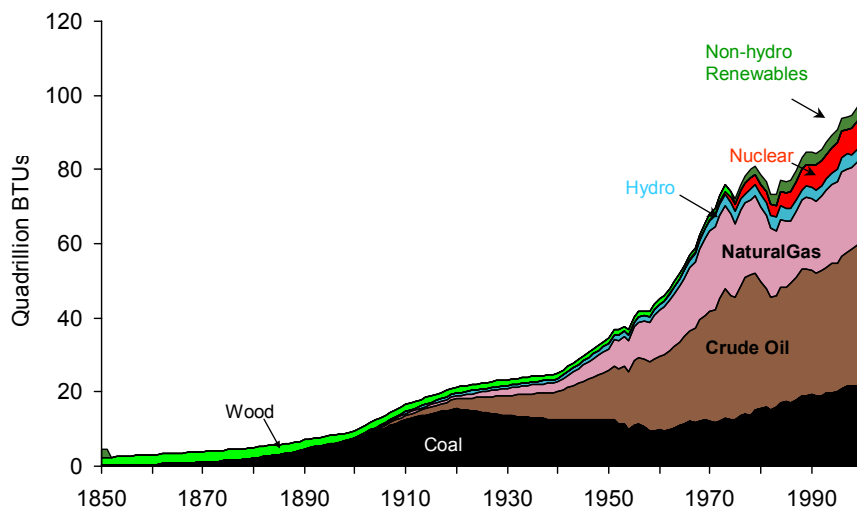
Bio-based Products

While all products made by Maine’s forest products industry – lumber, paper, biomass electricity, and wood products – are rightly referred to as “bio-based products”, for the purposes of this section, the term shall refer specifically to products derived through the chemical re-composition of woody biomass or byproduct (e.g. pulp mill sludge) into a new value-added material. This manufactured material may be a fuel, chemical, food additive, pharmaceutical, or other substance.

This section is not meant to serve as a definitive listing of potential bio-based products that could be produced in Maine, or to comment definitively on the economic and technical feasibility of producing particular bio-based products. The field of bio-based products is rapidly developing, and individual companies or research institutions hold as trade secrets much of the information on what is currently feasible. Instead, this section serves as an introduction to bio-based products and a discussion of some of the opportunities for and challenges to their development in Maine.

Energy consumption in the U.S. has grown dramatically over the last century, with fossil fuels such as coal, crude oil and natural gas providing the great bulk of the growth. With many predicting a peak in global oil production within the next twenty years, there may be an opportunity for bio-based products to replace fuel and other products that are currently derived from fossil fuels, or to capture growth in energy use.

Figure 93. U.S. Energy Consumption by Source, 1850 - 2000



Source: National Renewable Energy Laboratory



A growing number of academics, government officials, and businesses believe that bio-based products will provide a growing supply of fuel and chemicals. There are opportunities to build upon existing bio-based products (such as ethanol), and move existing or new products toward wood-based feedstocks.

Targets for a National Bio-Based Industry¹³⁴

Bio-Product	2000	2020
• Liquid Fuel	1% – 2%	10%
• Chemicals	10%	25%

Proponents of bio-based products cite a number of benefits that make these products superior to traditional (generally petroleum-based) products, including¹³⁵:

- Greenhouse gas reductions;
- Rural economic development;
- Security and diversity of energy supplies through use of domestically-sourced fuel;
- Use of a renewable resource;
- Urban air quality improvement; and
- Waste utilization.

These are all good and admirable reasons to pursue this technology. However, it must be remembered that from an investor’s point of view, any new project must be economically sustainable – it must provide a level of profit acceptable to the investor.

Emerging Products and Technologies

There is enormous opportunity to make many bio-based products from wood-based material, but a number of hurdles – technical and economic – remain. Through the middle of the 1900’s, it was not uncommon for paper mills to have large research and development departments that turned out a wide variety of products. The Brown Company in nearby Berlin, NH became famous for its ingenuity, and using wood developed products such as *Kreme Krisp*, a forerunner to today’s commercial cooking shortening.

In recent decades, researchers have concentrated most of their efforts at developing better and less expensive production of existing forest products, while other industries – such as petroleum refining – have developed a wide variety of chemicals and fuels. That may be about to change. Through its *Agenda 2020* program, the nation’s paper industry is

¹³⁴ Amidon, Thomas. “New Forest Based Materials Presentation.” Forum on Bio-Products Development: Opportunities for the Forest Products Industry. March 2, 2004.

¹³⁵ Hogan, Ed. *The Pyrolysis Bio-refinery Concept for the Production of Green Fuels and Chemicals*. Bio-oil Briefing Workshop, Concord, New Hampshire. August 16, 2002.



seeking to leverage research and development into new products that enhance and support the paper industry.

The production of bio-products is based upon “breaking down complex carbohydrates (compounds of carbon, hydrogen and oxygen) into their component sugars – analogous to how petroleum refineries break down complex hydrocarbons (compounds of carbon and hydrogen) into simpler chemicals, which are then built back up into desired fuels, plastics and other chemicals.”¹³⁶ The fundamental difference, of course, is that bio-products can be produced from renewable feedstocks. Wood and other plant material consists largely of cellulous (38-50%), hemicellulous (23-32%) and lignin (15-25%). Breaking these components down and reconstituting them in a consistent and cost-effective manner is the key to development of a meaningful bio-product industry.

Some advocates for bio-based products boldly proclaim that anything that can be made from petroleum can be made from wood or other bio-based feedstocks. This may well be true someday in the future, but today a number of technical and economic hurdles remain. Researchers now know that they can make ethanol from wood far more economically than in the past, and are moving forward on processes that will make this process competitive with other fuels from a cost perspective. The U.S. Department of Energy’s National Renewable Energy Laboratory (NREL) was recently recognized for developing a process that uses enzymes to turn cellulosic biomass (such as wood) into sugars – the base for chemicals and fuels. According to NREL, through this process “the cost of converting cellulosic biomass into usable sugars can be reduced by more than 20 times per gallon of ethanol produced.”¹³⁷

Products such as ethanol are attractive bio-based products because they have a known market, and known uses. While there would be some resistance from other (corn-based) ethanol producers and existing petroleum gas refiners, the product and its uses are established. For other products – many of which may not have developed markets and pricing -- one can expect a period of intense competition with other existing manufacturers, which will prove a serious challenge for a number of bio-based products. Opportunities are being initiated here in Maine that may position the state as a leader in some bio-product areas.

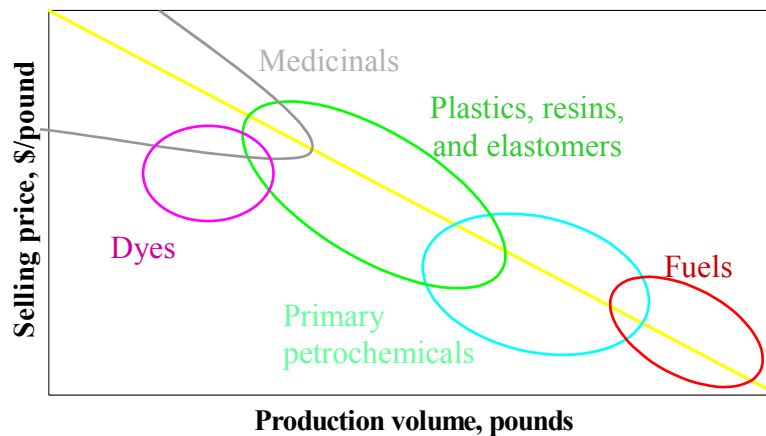
¹³⁶ National Renewable Energy Laboratory. *2003 Research Review*. April 2004.

¹³⁷ *SolarAccess.com*. “Biomass and Solar Technologies Lauded.” July 16, 2004.



Products that may be derived from wood (through a number of different processes) include cellulose-based fibers, fatty acids (used as lubricants), specialty celluloses, sterols (used in pharmaceuticals), essential oils, vitamins, aldehydes, bioactive polyphenols, proanthocyanids (an anti-oxidant), and taxans (used in pharmaceuticals)¹³⁸. The following figure shows classes and relative market / market price for a number of product types that can be derived from bio-products such as wood.

Figure 94. Selling price and market volume of bio-products¹³⁹.



Depending upon the feedstock (e.g., whole-tree chips, paper mill sludge, or sawmill residues) and process used, it may be possible or desirable to make more than one bio-based product or group of products at a given facility. In many cases, this may be economically necessary – the production of high volumes of a known product with a relatively stable market (e.g. ethanol) that allows a facility to get financing and operate while other, potentially higher-value, products are developed and brought to market -- may be the way bio-based products make a significant in-road into commercial production. Looking to the petroleum refining industry as a model, researchers have noted that:

“Fuels are the main product of mature petroleum refining processes, and this is likely to be the case for a mature biomass refining industry as well. There are few

¹³⁸ Chornet, Esteban. “River Valley Pyrolysis Project.” *Forum on Bio-Products Development: Opportunities for the Forest Products Industry*. March 2, 2004.

¹³⁹ Overend, Ralph P. “Biobased Products from Biomass Platforms.” *Forum on Bio-Products Development: Opportunities for the Forest Products Industry*. March 2, 2004.



organic chemicals and polymers with markets large enough to serve as primary products for one full-sized biomass refinery, especially when no single facility can expect to command full market share.”¹⁴⁰

Developing the Bio-based Products Industry in Maine

Maine’s forest products industry is well positioned to participate in and benefit from the development of a bio-based product industry. In Maine, there are essentially two models that could emerge:

1. **Stand-alone facility.** A facility could be developed to take in wood and produce chemicals, fuels, or both, using a number of processes. This could be a stand-alone greenfield (new) site, and would likely involve the production of a variety of products in order to provide economic diversity to the facility; or
2. **Co-location, or a move toward a “bio-refinery”.** A facility that uses part of the input or waste stream from an existing forest product manufacturer could co-locate, providing both entities with benefits. An example of this would be an ethanol producer that used paper mill sludge as a feedstock locating at the site of an existing Maine paper mill.

Each of these approaches presents opportunities and challenges. The paper industry’s *Agenda 2020* focuses on using existing infrastructure – pulp and paper mills – to improve the profitability of the existing paper industry and move toward a state where pulp and paper mills are the hub of a “bio-refinery” that produces a wide variety of products, including pulp, paper, fuels and chemicals.

As noted in a recent *Agenda 2020* publication:

“Advancing the Bio-Refinery: annual harvests from private forests in the U.S. is around 250 million dry tons of wood and bark. About 40 percent of this material is used for energy. Estimated 1990 energy yield from wood residues in the forest products industry alone was equivalent to 300 million barrels of oil worth \$8.8 billion. Applying bio-refinery technology to creating new value streams will more than double this value by 2030 through systematic improvements in forest productivity and biomass conversion technology.”¹⁴¹

¹⁴⁰ Lynd, Lee R., Charles Wyman, Mark Laser, Donald Johnson, Robert Landucci. *Strategic Biorefinery Analysis – Report 2: Analysis of Biorefineries*. Prepared for the National Renewable Energy Laboratory. November 2002.

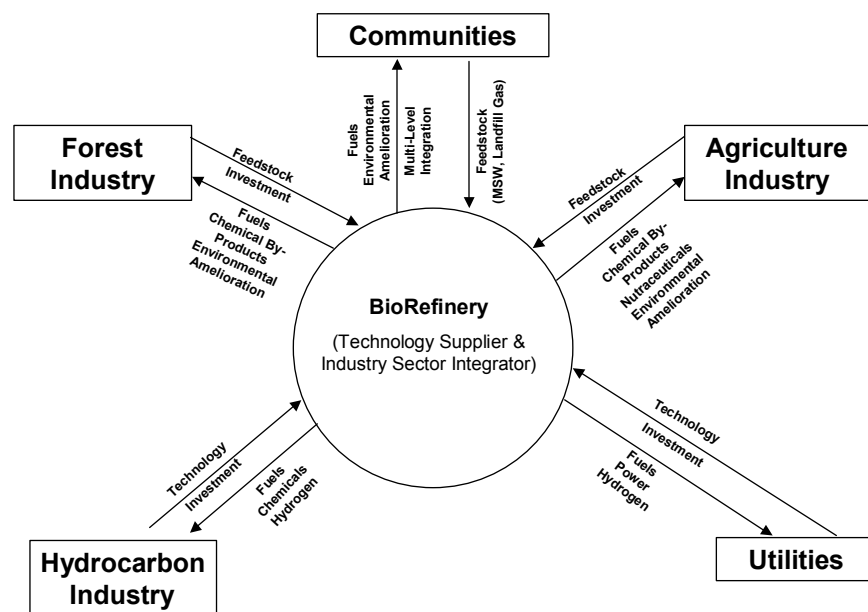
¹⁴¹ *Agenda 2020: Forest Products Industry Technology Alliance – 2003 Progress Report*. 2003.



There is research underway in the Northeast to extract value from fiber prior to pulping¹⁴² and to derive new values from residuals¹⁴³. There have been successes on a number of projects at the bench scale, and research is continuing to move these efforts toward commercial realization.

Eventually, this success in developing products compatible with pulp and paper production may move mills to a more complex and robust position, where they are producing a wide variety of products for a number of industries and yielding better overall profits.

Figure 95. Conceptual Bio-Refinery Schematic¹⁴⁴



Researchers have noted that there are a number of significant advantages of pursuing a bio-refinery, as compared to production of a single product.¹⁴⁵

- Revenues from high-value co-products may help reduce the selling price of the primary product, thus making it more competitive;

¹⁴² Amidon, Thomas. "New Forest Based Materials Presentation." *Forum on Bio-Products Development: Opportunities for the Forest Products Industry*. March 2, 2004.

¹⁴³ Lynd, Lee. "Biomass: Big Futures, Complementarity, & Next Steps." *Forum on Bio-Products Development: Opportunities for the Forest Products Industry*. March 2, 2004.

¹⁴⁴ Hogan, Ed. *The Pyrolysis Bio-refinery Concept for the Production of Green Fuels and Chemicals*. Bio-oil Briefing Workshop, Concord, New Hampshire. August 16, 2002.

¹⁴⁵ Lynd, Lee R., Charles Wyman, Mark Laser, Donald Johnson, Robert Landucci. *Strategic Biorefinery Analysis – Report 1: Review of Existing Refinery Examples*. Prepared for the National Renewable Energy Laboratory. November 2002.



- The economies of scale provided by a full-size biomass refinery lowers the processing costs of low-volume, high-value co-products;
- Biomass refineries maximize value generated from heterogeneous feedstock, making use of component fractions to produce a range of products; and
- Co-production can provide process integration benefits (i.e. meeting process energy requirements with electricity and steam co-generated from process residues).

Readers should note that the formation of a true “bio-refinery” is not expected in the near future. A number of technology and process hurdles must be addressed, and significant effort must be spent on deployment and commercialization, market development, and building the businesses to support these new products.

Moving Toward Commercialization in Maine

Moving bio-based products from concept to the lab to commercialization will prove challenging. Meeting these challenges will be necessary for development of a bio-products industry in Maine, and a realistic understanding of the challenges and opportunities that bio-products present will benefit all parties.

A wide variety of products can be made from wood and other bio-based material, and at some point in the future much of it will be made economically. This is likely a function not only of technology development, but of the price of the major input to most fuel and chemicals in production today – petroleum. If oil prices remain at current levels¹⁴⁶ or rise, the drive to develop and deploy bio-based products will be aided.

Maine has a vast supply of wood, often cited as a key bio-feedstock because of its year-round availability. While this is a strong benefit, Maine must remember that other regions have large quantities of wood available as well, and this may not serve as a significant competitive advantage. In fact, the wide variety of species available in Maine’s forest presents both an opportunity (a large number of potential feedstocks) and a challenge (possibility of large volumes of “non-homogenous” feedstock with ever changing makeup).

Depending upon the process and product, feedstocks other than wood can be used to develop bio-based products. One firm that seeks to produce a “bio-oil” using the pyrolysis process has bench tested over fifty feedstocks, including the following that have no or negative input cost¹⁴⁷:

- Corrugated cardboard;
- Corn hulls;
- Corn stover;
- Newsprint;

¹⁴⁶ \$51.25 on February 25, 2005 on the NYMEX, down from a recent high of \$55.17 a barrel on October 26, 2004.

¹⁴⁷ Dynamotive Energy Systems Corporation. *Bench Tested BioTherm Feedstocks*.



- Paper mill digested sludge;
- Rice hulls;
- Sugar cane bagasse;
- Wheat chaffe;
- Manure;
- Municipal Solid Waste; and
- Sewage sludge.

This company has focused its research and development efforts on wood, and to a lesser extent agricultural residues (e.g., sugar cane bagasse). However, even here Maine may face competitive challenges, as bio-based product companies may be focused first on those areas with low to negative cost feedstocks:

“The Company [Dynamotive] plans to unleash significant amounts of energy production, in the form of BioOil fuels, based upon utilization of abundant biomass waste streams from agricultural and forest operations and other post-industrial biomass residues. In many cases the feedstock sources are costly to dispose of and therefore are available at zero cost or are potentially revenue generating to then convert into BioOil.”¹⁴⁸

Similarly, the federally-funded National Renewable Energy Laboratory is “evaluating low-cost, potentially high-yield renewable feedstocks – agricultural residues, mixed plastics, trap grease, textiles, and other organic materials in the post-consumer waste stream” for their use in hydrogen production and other applications¹⁴⁹. Wood may prove preferable as a feedstock for a number of applications, but it is important to note that in many cases it may be a relatively expensive feedstock.

Commercialization of bio-products will be difficult, particularly within the paper industry. The industry generally has a lack of capital, a recent decline in technical entrepreneurship, and management that sees development of new product lines as outside of the core business. For these reasons, initial developers may be “over the fence” companies – firms that co-locate at an existing facility but have their own processes, staff, markets and financing.

New products, such as bio-based products, face a number of challenges. These include:

- Industrial acceptance (product risk profile),
- Competitive pricing to traditional products,
- Initial production and delivery hurdles,
- Lack of developed markets, and
- Intellectual property concerns.

¹⁴⁸ Dynamotive Energy Systems Corporation. *Annual Report*. 2001

¹⁴⁹ National Renewable Energy Laboratory. *2003 Research Review*. April 2004.



Due to these challenges and the financial uncertainty that goes with them, bio-based products are often held to a high economic threshold. One observer has indicated that the “compelling deal criteria” (point at which an investor would fund a project) for a bio-product facility would include a projected return on investment of 35%¹⁵⁰ -- double to triple what is required in other sectors of the forest products industry.

Federal Incentives to Develop Bio-based Products

Recognizing the potential of the bio-based product industry to provide new products from American forests and farms, the federal government has been active in promoting industry development. Federal orders or statutes promoting bio-based product development include:

- Executive Order 13134, *Developing and Promoting Biobased Products and Bioenergy* (August 1999);
- *Biomass Research and Development Act* of 2000;
- *Farm Security and Rural Investment Act* of 2002 (2002 Farm Bill); and
- *Healthy Forest Restoration Act* of 2003.

Of particular interest, the 2002 Farm Bill initiated a “Federal Biobased Product Preferred Procurement Program” (referred to as the FB4P), which will provide for procurement preferences for bio-based products that meet certain standards. The rules for this program are in development at this time, and will designate federal purchasing preferences for products in the following categories:

- Adhesives
- Construction materials and composites
- Fibers, paper and packaging
- Fuels and fuel additives
- Inks
- Landscaping materials and composted livestock and crop residue
- Lubricants and functional fluids
- Paints and coatings
- Plastics – monomers and polymers
- Solvents and cleaners, and
- Absorbents and adsorbents

Because the federal government, through its many agencies, is a very large consumer of a wide variety of products, this procurement preference may provide a major opportunity for newly developed bio-based products to enter the market and establish a base of customers and applications. For forest products, it is important to note that the proposed rules specifically exclude products with established markets, including “wood products

¹⁵⁰ Amidon, Thomas. “New Forest Based Materials Presentation.” *Forum on Bio-Products Development: Opportunities for the Forest Products Industry*. March 2, 2004.



made from traditionally harvested forest materials.”¹⁵¹ The federal government is also active in providing funding for increased research and development of bio-based products.

Case Study -- Opportunity Analysis of a Bio-Oil Facility in New Hampshire

In 2004, the New Hampshire Office of Energy & Planning commissioned a generic¹⁵² feasibility study for a bio-oil facility in that state. This analysis was part of the state’s effort to identify new markets for low-grade wood, and was conducted by Innovative Natural Resource Solutions LLC, with a Commercialization Plan conducted by Cole Hill Associates¹⁵³.

“Bio-oil” is an organic, liquid fuel produced through a process known as fast pyrolysis. Pyrolysis is a thermal process that rapidly heats biomass (such as wood) in an oxygen-free environment to a carefully controlled temperature, and then very quickly cools the volatile products formed during the reaction. This procedure produces three products: a liquid, char, and gas. The liquid, roughly 75% of the output, is referred to as “bio-oil”.

Bio-oil can be burned to produce heat and electricity, and many see it as an intermediary to a number of higher-value chemicals, pharmaceuticals, and food additives. While some work has been conducted in this area, most of the chemicals that could be derived from bio-oil have not been isolated at the commercial level, and doing so may prove extremely challenging.

The analysis considers a variety of locations and economic variables in order to assess feasibility. All scenarios considered in the commercialization plan assume the generation and sale of electricity as a significant part of the project. Economic and other assumptions used in the Commercialization Plan support a conclusion that bio-oil production and marketing are feasible economically and environmentally under the circumstances specified. It must be noted that this conclusion is based upon a number of assumptions that have not been fully tested in the marketplace.

¹⁵¹ *Federal Register* Volume 68, No. 244, December 19, 2003.

¹⁵² This study did not identify a particular site for the facility, operator, management team or particular technology to be licensed.

¹⁵³ This complete analysis, including the feasibility study, commercialization plan, and supporting spreadsheets is available at the New Hampshire Office of Energy & Planning website, <http://www.nh.gov/oep/programs/energy/bioOil.htm>



Outlook

Maine's forest products industry may be well-positioned to benefit from the development of some new bio-based products. However, caution is necessary, as commercial success in this arena is easier said than done.

A number of factors favor an expansion of bio-based product development in Maine, including global momentum for bio-based energy and products, technology advances, and some existing infrastructure (e.g. some paper mills) that must identify new revenue sources in order to remain economically viable. If the intellectual property associated with development of new bio-products is adequately protected, this may serve as an area where Maine can develop a lasting competitive advantage.

There are two key pieces to moving toward development of commercially feasible bio-based products in Maine:

1. *Investing in R&D.* An enormous amount of work remains to be done in the vast field of bio-products, and this will happen best if public and private sector investment is made to solve some of the technical challenges that exist for turning wood fiber and wood manufacturing residues into value-added products; and
2. *Encouraging a rapid deployment of new technologies.* Once new technologies are developed, Maine should work with companies to rapidly bring the product to commercial applications. As noted in the paper industry's *Agenda 2020* publication, "cutting edge research is worthless if it's not swiftly deployed."¹⁵⁴

Maine is fortunate to have two organizations that recognize the potential of bio-based products in Maine and are working toward development of centers where continued research, development and deployment can be undertaken. The University of Maine, with its world-class research faculty in paper, chemical engineering, and wood composites – as well as the presence of a pilot paper machine – has great promise as a leading developer of new technologies¹⁵⁵. Additionally, the River Valley Growth Council, a community-based economic development corporation in Rumford, has been working to establish a bio-development product center at that location. Maine recently received nearly \$1 million in grants from the U.S. Department of Energy for forest-based bio-product research and development, seeking to "establish forest biomass as a significant source of sustainable fuels, heat, power, chemicals and materials."¹⁵⁶

¹⁵⁴ Moore, Henson. In *Agenda 2020: Forest Products Industry Technology Alliance – 2003 Progress Report*. 2003.

¹⁵⁵ Goad, Meredith. "Scientists mix chemistry, eco-safety, find solutions." *Portland Press Herald*. October 26, 2004.

¹⁵⁶ *Portland Press Herald*. "Federal grants support forest bio-products research." September 22, 2004.

