Challenges and Opportunities for the Northeastern Forest Bioindustry

Introduction

In recent years, rising and increasingly volatile energy costs have combined with growing concerns over global climate change to fuel interest in the development of carbon-neutral, sustainable energy sources. Throughout the U.S. and abroad, a host of policies and research initiatives are in progress to address economic and technological barriers that restrain the transition to a sustainable "bioindustry." In the U.S., the Energy Independence and Security Act (EISA), passed in December of 2007, mandates a 5-fold increase in biofuel production over the next 15 years, with 60% (22 billion gallons/year) to be derived from cellulosic or non-corn feed stocks – including woody biomass.

Producing sufficient feedstock for the challenge ahead has spurred a growing number of studies on biomass availability. Perlack *et al.* (2005) found that for the U.S. as a whole, the largest potential share of sustainable feedstock will continue to be derived from crop residues (446 million dry tons (mmdt/year)), followed by perennial crops (377 mmdt/year) and forest and wood residues (370 mmdt/year). This is not to suggest that the only renewable energy options for the Northeast U.S. will be from biomass for, as identified by Short (2008), several other sources should be considered including solar, wind, and water. If the above projections are true, however, it is likely that biomass harvested directly from the forest will play an important role in creating and sustaining the bioindustry.

The seven states of the Northeastern U.S. (Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) have abundant forest resources and an established forest sector. The emerging bioindustry offers great opportunities in using these resources to offset energy needs, but realizing this potential will take a coordinated effort by both the public and private sectors. This paper examines the opportunities and challenges the Northeastern U.S. faces in using forest biomass as a feedstock for the emerging forest-based bioindustry. We first summarize proven and "near-to-market" forest-based processes and technologies, and then highlight key aspects of the region's forest resources. These issues provide the framework for the bioindustry, but many other critical pieces must be in place before this industry can develop in a sustainable manner. We show that careful consideration must also be given to feedstock specifications, existing facilities and infrastructure, forest operations, public policy, and the wide range of social values likely to emerge as the industry grows.

The Forest Bioindustry

The Northeast bioindustry includes proven technologies related to bioenergy such as electricity generation, heat-only facilities, and co-gen facilities combining both heat and power. Wood-chip fired biomass electricity-only plants are estimated to operate with efficiencies in the range of 28% (electric energy generated/total energy available in the wood fuel used) (Timmons *et al.* 2007a). This low level of efficiency suggests a natural fit for co-locating industrial operations requiring heat with biomass-fired electricity generating facilities.

Bioenergy facilities have a long history in the Region. Wood residues from integrated sawmill operations have been used for decades to generate combined heat and power for mill operations. The oil crisis in the 1970s which spawned many wood to energy initiatives including Burlington Electric Department's McNeil Generating Station which has been in operation since 1984 (Irving 2002). Vermont's "Fuels for Schools" program, which started in the 1980s and now serves 20% of Vermont public school students, is responsible for heating 32 schools with wood chip systems (McElroy 2007).

The above technologies may be new to specific geographic areas and/or applications and as such, they represent an important near-term source of potential demand for forest biomass. One projection for Southern New England estimated that Connecticut, Massachusetts, and Rhode Island would generate a total renewable energy demand of 6.9 Giga-Watt-hours in 2015 (Timmons *et al.* 2007a) as a result of public policies requiring renewable power generation. Grace and Corey (2002) estimate that 29% of this energy will be generated by biomass-fired electricity generating plants. With current technology, this level of additional biomass-fired electricity would require approximately 2.6 million green tons of wood chips annually. Mount Wachusett Community College in Gardner, Massachusetts, recently installed a wood-chip fired hot-water heating system for the 450,000 ft^2 of building space on its campus. The system delivers 8 million BTU/hour, saving the campus $276,000/yr compared to its original electric heating system (Mount Wachusett Community College 2008). Maine's recently announced "Wood-to-Energy" initiative envisions a school heating program similar to Vermont's, along with several pilot wood pellet projects.

The Northeast bioindustry also includes near-to-market products and technologies related to biofuels and bioproducts. Technologies that convert wood to biofuels such as cellulosic ethanol, as well as a growing list of other bioproducts, are in varying stages of development and commercialization. Currently, the majority of ethanol is derived from corn feedstock, which is grown and processed largely outside of the Northeast. Given its abundant forest cover, however, the Northeast has great potential to supply forest-derived biomass for ethanol production, with additional supplies likely from perennial crops (Timmons *et al.* 2007b) and, to a lesser degree, annual crops. Biorefineries like the one planned for Old Town, Maine (see side bar) are envisioned to be able to convert forest biomass into ethanol as well as a range of additional value-added products, with a goal of maximizing the profit potential of the end-product mix. Nace (2007) gives an idea of what the product stream from such a biorefinery might include. Using cellulosic biomass as an input feedstock, a biorefinery may produce biodiesel derived from levulinic acid (a high-BTU char product) and other commodity acids, and value-added chemicals that could be used as feedstock for the polymer, plastics, pharmaceuticals, and chemicals industries. All of these technologies and products are being developed with the expectation that forest biomass will be at least one component of the feedstock.

The Resource

The seven-state Northeastern Region is endowed with abundant forest resources. Within the Region, however, the distribution of species and biomass is uneven, with southern portions tending toward scattered hardwood stands in fragmented parcels set amid rapidly urbanizing communities. In contrast, much of northern Maine is dominated by softwood species within an undeveloped landscape of what were once large industrial ownerships that are now rapidly fragmenting.

Throughout the Region, forest acreage, stand volumes, and growth have been increasing since historic lows in the mid-1800s. Currently, the Region boasts an average accessible forest land cover of 70.6%, ranging from a low of 52.8% in Rhode Island, to a high of 88.4% in Maine (USDA Forest Service 2008). Based on 2001-2005 inventories, total accessible forest land area totals 49.9 million acres. Given many differences in development, population, and timber supply across the Region, it is expected that development of a bioindustry is likely to come from the northern forest region which is comprised of 21 million acres of forestland from upstate New York to Maine (Short 2008).

Given the rapid pace of technological development in the area of forest-based bioproducts, little is known about the relative values and future market potential for the Region's tree species. The most recent USDA Forest Service Forest Inventory Analysis data show that growth exceeds removals for the growing stock of hardwoods on timberlands. Most recent data indicate annual growth of hardwood growing stock in the seven states is 877 million cubic feet, with only 500 million cubic feet in annual removals. New York has the largest net hardwood growth of about 229 million cubic feet of annually.

The softwood resource condition is less certain. Recent softwood harvest rates in Maine and New Hampshire contribute to a net reduction in overall softwood growing stock levels for the Region. This trend may have changed, however, with the recent housing slow-down and divestitures of large industrial timberland holdings in Maine and elsewhere. Data for the remaining five states show that, for softwood growing stock, growth exceeds removals by a ratio of nearly 2:1. For Connecticut, Massachusetts, New York, Rhode Island and Vermont, combined annual growth of the softwood growing stock was reported at 197 million cubic feet, with only 104 million cubic feet of removals.

Forests in the Northeast are largely under private ownership, although the last decade has witnessed significant changes in ownership class, land use, and parcel fragmentation. In remote northern areas of the Region, large industrial ownerships have been sold off to a host of financial groups like TIMOs and REITs (Hagan *et al.* 2005). In more populated areas to the south, development pressures have lead to the steady conversion of forests and farmlands for residential and commercial use (Stein *et al.* 2005). In both cases, fragmentation of large tracts into smaller parcels is a dominant process across the landscape.

The heavy representation of non-industrial private forest (NIPF) ownership suggests a highly decentralized resource that can readily respond to market signals such as higher prices. Moreover, widespread distribution of the resource limits the need to transport raw material over large distances, favoring the emergence of an industry based on local processing and supply systems. In addition, landowners are generally familiar with timber growing and harvesting practices, with a host of institutions and regulations in place to foster a competitive market for timber while protecting lands for the continued production of both commodities and ecosystem services. Finally, the Region has some of the highest levels of third-party environmental certification in the country. For example, Maine leads the nation with nearly 7 million certified acres, including 500,000 acres of public land, 6 million acres of large-parcel private lands, and 350,000 acres of smaller private lands (Maine Forest Service 2005).

While current resources appear sufficient to support an emerging bioproducts industry, growing development pressures and forest ownership fragmentation are likely to increasingly impact future resource supplies. First, the rapid development and urbanization taking place across the Region permanently removes lands from the forest base. In addition, a growing number of studies have shown decreased willingness by landowners to invest in stand management and engage in timber harvests as forests are fragmented and population densities increase (Alig *et al.* 2004, Stein *et al.* 2005). Another consideration for timber management and long-term access to timber supplies is the growing number of acres under conservation easements (deGooyer and Capen 2004). Although conservation easements do not preclude harvesting by definition, they are often associated with restricted access for timber production. How these changes ultimately impact the availability of forest resources is of considerable interest and warrants further study.

The Opportunities and Challenges

Established technologies and products, combined with an available resource at the Regional level, provide a generally positive outlook for the emergence of a forest-based bioindustry in the Northeast. Yet there are many additional pieces to this puzzle that will ultimately determine whether or not the industry can prosper. For example, the degree to which feedstock needs overlap between new bioproducts industries and the traditional forest products industry will in large part determine the level of competition for raw materials. Moreover, an extensive industrial infrastructure is required to bring even the most basic technology to commercial operation. This includes the industrial facility itself, as well as the entire forest operations supply chain. In addition, public policy decisions at all levels of governance can have significant impacts on emerging and established sectors of the forest industry. As noted above, given the Northeast's largely private and fragmented ownership, any policies must consider a broad array of landowner and management objectives, as well as a broader range of social values likely to emerge along with the industry.

Feedstock Specifications

Despite the Northeast's abundant forest resource, production rates in the short-term are determined by existing logging capacities. In addition, much of the available material is already being used by the existing forest industry. As a result, new forest-based bioproducts facilities need to understand their own feedstock specifications in order to successfully compete for raw materials, or, better yet, integrate their operations into existing facilities. One example where competition for feedstock is likely to occur is between bioenergy plants and pulp mills. Indeed, both facilities use wood in comminuted form, and pulp-quality wood chips (bark free and uniform size) would work well in a bioenergy plant. The reverse is not true, however, since whole-tree chips used in bioenergy plants contain more contaminants and bark than would be acceptable by a pulp mill. As a result, and depending on distance between facilities and overlap in their respective wood baskets, wood chip prices may rise due to increasing competition between facilities.

In contrast, an example of an integrated approach is that proposed by Red Shield Environmental, where hemicellulose is extracted from wood chips prior to the pulping process (Arnold 2007). Cellulosic ethanol is to be made from the hemicellulose without affecting the pulping process or product quality. This integrated approach offers obvious advantages, but since market forces cannot be controlled, new wood-using facilities -- regardless of the specific technology or product -- must have realistic expectations regarding long-term feedstock price and availability.

Industrial Facilities

The Northeastern Region's existing industrial sites represent a key asset for the emerging forest-based bioindustry. Many pulp and paper facilities have excess capacity due to previous scale backs, and as a result offer opportunities for co-location of bioproduct processing facilities. These sites not only have human resources, procurement policies, and timber supply networks in place, but also access to utilities (e.g., water, electricity, natural gas, oil supplies), and waste treatment facilities (e.g., wastewater, solids and sludge, ash). Existing sites are also well positioned with respect to production inputs (e.g., zero or low-cost inputs like black liquor, processing wastes and byproducts), and transport systems for both inputs and finished products via roads, barges and railways. Existing sites may have liabilities stemming from past environmental waste hazards, and just because an industrial site exists does not mean that public acceptance will be forthcoming when it comes to altered or expanded uses – even in communities under economic stress (Moreira 2006).

Size of operation is also important. Given the rapidly evolving nature of the bioindustry and associated technologies, a range of scales is possible – an advantage given the diversity of possible facility locations in the Region. Some emerging biomass technologies such as gasifiers can operate at a small scale, with the advantage of having a small environmental footprint (Weaver 2007). Others, however, require a large physical plant of 70,000 to 100,000 ft^2; the ability to procure, store and move massive quantities of biomass; and the need for both inside and outside storage (Nace 2007, Kingsley 2007). In this regard, the scale of proposed liquid fuels facilities (e.g., large-scale ethanol production) may be too large for this region. From a feedstock perspective, biomass fuel is already a large business in the Northeast, with 5.4 million tons of usage in 2005 and $75-100 million in delivered value (Irland 2007). Still, for some Northeast states, significant long-term investment is needed to make efficient use of forest biomass – especially in terms of logging infrastructure as described below.

Despite the Region's abundance of forests and existing wood processing facilities, challenges exist. First, bioproducts processors will have to successfully compete against existing wood buyers, a challenge heightened by the significant quantities of wood under long-term procurement agreements (Kingsley 2008). Moreover, current biomass prices are already pushing the limits of conversion technologies, so that increased competition for supplies will raise prices and squeeze profit margins even more. Adding to these risks is the absence of long-term pricing options such as is available for corn, which makes it difficult to forecast input costs subject to volatility in biomass prices (Kingsley 2007).

Fortunately, the assumption that biomass prices will always increase is open to debate. This is important given the tight margins of many existing technologies. For example, Kingsley (2007) found that one chip truck with 30 tons of green chips can produce

0.6 MWH of electricity or 40 gallons of ethanol. At $30/ton delivered, electricity generating costs would exceed $0.05/kwh excluding facility costs (e.g., staffing, maintenance, etc) and before profit. Similar scenarios apply for ethanol. Ironically, the Region's forest products sector's divestment of land from mills over the last 15 years may add needed flexibility and competition to the supply side of the market.

Product distribution for market and/or additional processing is another consideration. Rail unit-cars are the most effective mode of transport for ethanol, but this option is lacking in the Region given its highly fragmented ownership of existing rail lines. In addition, the Region has limited proximity to ethanol refineries, with the closest in Shelby, New York (Renewable Fuels Association 2008), and large-scale facilities in New Jersey. Such distances limit access to market, although the Region's relative proximity to refineries and population centers may still place it at an advantage to corn-based ethanol produced in the Midwest.

The Region's high energy costs present both opportunities and challenges. High electricity costs in the Northeast can limit the viability of launching a successful bioproducts operation. Alternatively, many facilities have on-site electrical generating capacity (commonly on the order of 7-10 MW of power) and can sell power back to the grid. High energy costs may also create local markets for home heating substitutes like bio-oil and wood pellets. Similar opportunities are likely to exist for excess steam-generating capacity, as well as waste heat recovery in processing.

Forest Operations

Just as the Region's abundant forests and existing wood products facilities present opportunities and challenges to the emerging bioindustry, so does the existence of a long-established forest operations sector. Additional raw materials can be supplied through increased harvesting activity, and/or more intensive harvests (i.e., leaving less logging residue on-site). Opportunities exist to offset management and silvicultural costs through biomass harvesting, thereby promoting management and increasing stand productivity. Other opportunities exist for forest and ecosystem health and restoration from future insect and/or disease epidemics. In addition, many stands in the Region are overstocked with small-diameter trees and could benefit silviculturally from what would traditionally be considered pre-commercial thinning. For example, in Maine 10% of the forestland (1.75 million acres) is overstocked and in the sapling stage of development (McWilliams *et al.* 2005). In some areas, such harvests could also reduce fuel loads and wildfire risk – especially in rapidly urbanizing areas near metropolitan centers. For those opportunities to be realized, a healthy forest operations infrastructure is required.

Forest operations are central for the supply of raw material to the entire forest products industry. Traditionally, the focus has been on round wood products. Trees are harvested and transported to roadside for processing after which they are delivered to wood using facilities. Conceptually this supply chain is simple, but in reality it is rather complex. The logging and trucking industry in the Northeast is comprised of many independent contractors that provide a service to a diverse group of landowners and supply multiple wood-using facilities. The form of wood delivered to roadside varies, as does the amount and type of processing on the landing. Decisions of this nature depend on several factors including equipment availability, mill demands, site characteristics, and stand conditions. Extensive road networks are critical to efficient transportation of forest products and advanced communication and satellite technology are often used to improve efficiencies in production. Cost of production is a constant focus throughout the supply chain for all forest products and biomass is no exception.

Several additional challenges exist for forest operations to supply forest biomass to the bioproducts industry. Logging residue has a low bulk density which presents handling difficulties for all aspects of forest operations. It is also possible that specifications will be established by the bioindustry for raw material characteristics (e.g., species composition, bark content, and chip size), depending on which technology is used. This will further complicate handling and sorting. Extraction of forest biomass presents a compromise in economic, environmental, and social values. Each of these challenges will have to be addressed to ensure a stable supply of forest biomass to the bioproducts industry.

Handling forest biomass presents the greatest challenge for forest operations because logging residue has a low bulk density. The proportion of solids in logging residue and chips is less than 20% (Anderson *et al.* 2002). Compared to handling roundwood, it is simply more awkward and inefficient to work with logging residue. Eckardt (2007) identifies harvesting, accumulation, processing, and transport as four required phases for conversion of forest biomass into a usable form for bioproduct facilities. Handling logging residue in each of those phases is difficult because existing logging equipment is largely designed to handle roundwood. Specialized equipment has been designed to facilitate that process and is commercially available (Anderson *et al.* 2002, Turner 2005, CBI 2006, Paiement 2008), but these machines represent significant capital investment and hence additional cost for contractors. With respect to trucking, it is difficult to achieve full payload of biomass in chips vans (Anderson *et al.* 2002).

Furthermore, all forest biomass is not created equal. If a given bioproduct technology requires a specific quality of raw material defined by species, bark content, size distribution, or contaminant limits, forest operations will need to increase sorting at roadside. The opportunity that this creates for forest operations in the bioproducts industry is one of service. New harvesting, comminution, and sorting technologies may be required and additional handling will increase costs, but forest operations can increase value to the supply chain in that regard. For this to occur, bioproducts facilities will have to communicate their needs to forest biomass suppliers. Pricing will also need to reflect the realities of added costs associated with harvest and processing.

Balancing economics with environmental concerns related to water quality, soils, and forest biodiversity is a greater challenge with forest biomass harvesting. A standing dead tree can be habitat for wildlife, can be used in skid trails to reduce soil compaction and erosion, and can be harvested as biomass. Logging residue can be left scattered throughout a site to decompose, can be used in trails, or can be processed as biomass. Often, the logging contractor or operator is left to make that decision. Other times, requirements are set by third-party environmental certification standards like those found under SFI. Since these decisions require tradeoffs, it is important for proper guidelines and policies to be in place to help landowners, contractors and foresters make informed decisions in this regard (Minnesota Forest Resources Council 2007).

For the region as a whole, the same challenges that currently face the forest products industry will confront the bioindustry. Many of these issues are localized and include truck weight limits, labor issues, inefficiencies in the supply chain, wait times at mills, rising logging and energy costs. There must be excess capacity within the existing system to supply biomass, otherwise the bioindustry will have to compete with traditional wood using facilities for contractor services. As a result, an increased demand for forest biomass will not solve existing challenges, and may in fact exacerbate them.

Public Policy

Public policy represents both an opportunity and a challenge to the growth of the Region's forest-based bioproducts industry (Solomon et al. 2007). Support comes in the form of legislation at both state and federal levels. Stokes (2007) points to at least 10 federal policies, most involving the Department of Energy, that seek to foster biomass development. At the other end are growing regulations over forest practices, BMPs, certification, shoreland protection, vernal pools and deer winter areas. These measures are important in protecting environmental quality, but often increase harvest costs and limit resource availability – at least in the short-term.

A host of policy interventions have the potential to foster the bioindustry while advancing long-standing efforts to aid rural economic development (Breger 2007, Timmons *et al.* 2007a). This, combined with growing concern over energy costs and the steady erosion of the manufacturing sector, suggests a favorable political climate toward the bioindustry cluster. For example, new wood pellet plants create rural jobs, reduce energy costs, and recycle energy expenditures within state and local economies. Biomass facilities are a significant tax source for host communities, with perhaps 150-250 new jobs created by each new bioproducts facility (Irland 2007). Revitalizing pulp and paper mills through the co-location of biorefineries has the potential to increase value-added and enhance competitiveness within the industry.

At present, the growth potential and structure of the bioindustry is uncertain, but recent examples suggest substantial gains in both jobs and economic output. Timmons *et al.* (2007a) estimated the potential economic impacts from developing new biomass energy generation in Massachusetts by 2015. Their findings indicated a likely "build-out" of 165 megawatts (MW) of new biomass-fired electricity generation. This would generate 1,000 new jobs and $97 million in additional annual economic output during a 5-year construction phase. On-going supply and generation activities would total approximately 600 permanent new jobs and $79 million in combined annual economic output. And this represents just one business segment -- biomass electricity generation -- in only one state in the Region. Clearly, the potential for the entire bioindustry could represent tens of thousands of new jobs and potentially billions of dollars in regional economic activity in the medium-term future. This development might particularly benefit mill communities that have been negatively impacted by recent plant closures and cutbacks.

The speed of permitting new facilities and even expansion plans has been identified as a key factor in project timeline and economic feasibility (Kinglsey 2007). Given the large capitalization costs and uncertain markets, there are needs for tax credits and a clear, long-term commitment to nurturing the industry. High capital costs for building and/or retrofitting plants, combined with the perception that Maine and other New England states are not "business friendly" (due to taxes and regulatory bureaucracy) may limit the willingness of firms to make the necessary investments in the sector. As a result, the co-location of new facilities on or near existing sites can reduce these costs, with the added benefit of an existing trained work force.

On the revenue side, Renewable Portfolio Standards (RPS) is an example of state-level government policies that favor the development of biomass energy facilities. RPS policies, such as those adopted by Massachusetts, Connecticut, and Rhode Island, seek to diversify energy sources, reduce energy price volatility, and foster green-energy and rural economic development while decreasing fossil fuel use, greenhouse gas emissions, and dependence on imported energy (Breger 2007). The Massachusetts policy provides additional incentive through a provision that grants Renewable Energy Certificates (REC) to approved producers. These certificates represent the environmental attribute that the electricity was generated from a renewable energy facility and are traded on a market. REC values have recently been trading in the area of $0.05 per kWh, which represents a substantial premium for renewable energy providers.

As currently configured, RPS programs in the Region exclude most older biomass plants, although these facilities can apply for credits on incremental improvements in technology (Breger 2007). While RPS programs may stimulate interest in the use of biomass for electrical power generation, they do little to improve logging infrastructure and capacity, leaving developers with significant fuel procurement risks. Also, since RPS programs apply to electricity generating facilities, they in-effect disadvantage other bioproduct technologies that are ineligible for REC credits. For example, the use of biomass for thermal applications is also not recognized under RPS programs.

State participation in RPS programs vary, but several of the Northeastern states are providing real dollars to developers of bioenergy facilities. Moreover, public acceptance of biomass energy facilities is likely to be enhanced by the low emissions standards set in RPS, presenting an opportunity to challenge old ways of thinking that burning biomass is bad for the environment (Roe et al. 2001). RPS programs are in the public policy domain and subject to the legislative process, so although they are providing incentive currently, such programs are always subject to change.

Finally, sustaining interest in bioproducts development in an era of increasingly volatile oil prices raises serious concerns to the sector's proponents – especially for those who witnessed the rise and fall of the 1980s renewable energy boom. Then, falling oil prices undermined the demand for renewable energy, leaving many on the production-side of the sector with expensive and specialized equipment sitting idle. Similar risks accompany uncertainties over future REC earnings, biomass prices and availability, and feedstock supply infrastructure. Fortunately, the growing recognition of the need for a comprehensive energy policy at both state and federal levels may avoid the repeating of past mistakes.

Social Values

Finally, as the forest bioindustry develops in the Region, it must continually assess and respond to how it is perceived by a variety of stakeholder groups (Elghali et al. 2007). Within the forest sector itself, primary stakeholders include forestland owners, loggers and truckers, and processors. Each of these groups potentially hold different views and interests regarding the industry. For example, large industrial forestland owners are well acquainted with biomass operations, while small non-industrial owners are not. How these groups view industry-driven changes in harvest practices is anyone's guess, but initial research suggests that increased biomass removals from stands will raise concerns over long-term site productivity, water quality, and wildlife habitat (Sample 2007). For loggers and truckers, the industry's need for new equipment like chippers and chip vans could be difficult given aging demographics (Egan and Taggart 2004, Baker and Greene 2007) and lingering skepticism from the collapse of the biomass industry in the 1980s. Finally, existing wood processors are unlikely to welcome increased competition for wood supplies, although new enterprises that generate demand for waste or increase competition for byproducts like sawdust would be viewed favorably (Bolkesjo et al. 2006).

Secondary stakeholders have a host of other interests not directly tied to the growing, harvest, transport, and processing of timber. These range from local governments, civic organizations and the general population, to environmental NGOs and the business community. Here, views towards the emergence of a bioindustry are likely to span the gamut from enthusiastic support to caution or even outright opposition (Buchholz et al. 2007).

Business interests and local government officials will likely endorse new jobs and opportunities to capture value-added production while reducing the outflow of dollars to purchase imported fossil fuels (Short 2008). For the environmental community, stakeholder perceptions are likely to be complex, with the benefits of bioproducts as a carbon neutral, sustainable replacement for fossil fuels being offset by concerns over the environmental impacts of increased harvesting pressures on forestlands (Righelato and Spracklen 2007).

It is likely that stakeholders will evaluate the impacts of an emerging forest bioindustry based on expected impacts on the forest resource, processing, and end use (Lilieholm 2007). These views will be dynamic and subject to wide uncertainties (McCormick and Kaberger 2007). They will also likely exhibit geographic variation, with rural resource-based residents and communities favoring forest sector growth, while more ecologically-conscious suburban and urban residents expressing concerns over environmental tradeoffs (Lowe and Pinhey 1982). As a result, efforts will be needed to understand and respond to stakeholder concerns as they emerge. Failure to do so could cause conflict later.

Conclusions

The key to success for the Northeast forest bioindustry is to bring the abundant forest resource and emerging technologies together in a manner which compliments the Region's infrastructure, forest operations sector, public policies, and social values. Challenges that are currently facing the forest products industry will be magnified by the emerging bioindustry if they are not addressed now. A healthy forest operations community is critical to the success of this industry. Not all technologies and products within the forest bioindustry are complimentary to each other or to the existing forest products industry. Integration of new technologies into existing facilities and taking advantage of the available infrastructure is one way to increase the profitability and flexibility of an operation. Further research is needed into the social values held by the varied stakeholders, and what impact those views may have on the supply of raw material for the bioindustry, processing practices, and demand for the products. Well-planned policies related to all aspects of the bioindustry are crucial to eventual success. For example, climate change policies expected by the new federal administration will likely be favorable to the forest bioindustry. All of these pieces must come together in the right way for the entire bioindustry "puzzle" to be complete. Difficult and strategic decisions are required to overcome the many challenges described above, but the opportunity to create a thriving and sustainable bioindustry and ultimately reduce our dependence on fossil fuels necessitates the effort.

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