Michael Jacobson · Daniel Ciolkosz
*Editors*

# Wood-Based Energy in the Northern Forests

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ISBN 978-1-4614-9477-5 ISBN 978-1-4614-9478-2 (eBook)
DOI 10.1007/978-1-4614-9478-2
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013955039



Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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# Chapter 1
# Introduction and Overview

**Michael Jacobson and Daniel Ciolkosz**

This volume of papers grew from a Penn State short course on developing wood bioenergy projects, held in November 2011. It was intended as a hands-on course to better identify winning scenarios, avoid costly mistakes, and develop biomass projects that are truly sustainable. The course focused around a bioenergy case study where participants actually developed a biomass project. Given the focused nature of the short course, additional papers for this volume were solicited to provide the reader with a comprehensive snapshot of wood energy in the Northeast. What emerged is a fascinating collection of analysis and discussion on some key issues related to wood energy in the Northern Forest, with special focus on the Northeast United States.[1] The topic is very broad, involving science, engineering, business, and society. The chapters of this volume are similarly diverse, ranging from careful scientific analysis to practical guidance to regional history and so on.

The book's goal is to provide the reader with a sense of the state of woody biomass development in the Northeast region, as well as an overview of the issues in scaling up its production and utilization. Most chapters provide practical hands-on advice for the practitioner, so a key audience is anyone developing a woody bioenergy project.

The book starts with an overview of the state of bioenergy in the Northeast including its availability, economics and environmental aspects of the resource. Then the book shifts to production, harvesting, processing, and uses of bioenergy. Following chapters cover harvesting systems, pellets, residential (heat) and

[1] For the purposes of this book, we will consider the Northeast United States to include the 12 states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Maryland, Delaware, and West Virginia.

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M. Jacobson and D. Ciolkosz (eds.), *Wood-Based Energy in the Northern Forests*,
DOI 10.1007/978-1-4614-9478-2_1, © Springer Science+Business Media New York 2013

nonresidential—commercial/industrial (heat and power) and liquid fuels. Finally, the book addresses community (e.g., health effects), social, and financial considerations.

Interest in woody biomass is growing, in part because it is a renewable energy source, but also because the technologies and costs for its use have improved dramatically in recent years. From an environmental perspective, wood biomass has several advantages compared to fossil fuel. These include lower carbon emissions, reduced threats of acid rain, and low particulate emissions if standard emission control devices are used. In addition, using woody biomass can be a tool to help regenerate the forest and improve forest health, biodiversity, and wildlife habitat. From a socioeconomic perspective, locally produced wood biomass strengthens local economies and provides better energy security. Another benefit is that there are multiple and diverse sources of biomass available which can keep costs stable over time. Compared to other renewable energy sources as such as solar and wind, biomass is the only one that can be effectively stored and delivered when needed.

One of the benefits of bioenergy compared to other renewables such as solar or wind energy is its usability in all energy sectors. Chapters 6–10 discuss these uses. Its most common and oldest use in the Northeast is for *thermal* applications, namely wood stoves, pellets, heat for schools, hospitals, and other such community scale institutions. Some facilities are also using biomass for *combined heat and power* (CHP) systems. In addition, the *electricity* sector has existing and proposed wood-fired or co-fired power plants across the region. Finally, and not yet in full commercial production are *liquid fuels*, such as cellulosic ethanol. The potential for expanding the use of wood in all these energy sectors is significant in the Northeast, especially thermal due to the region's high dependence on costly heating oil in the winter months.

In the Northeast, biomass for thermal energy needs (space and process heat) is the most practical use at this point in time and has significant near-term growth potential. The forest products industry has long used wood for heating their facilities, but now its use has grown for residential, commercial, and industrial applications as well. Chapters 7 and 8 focus on residential and nonresidential combustion systems. New heating systems are emerging as are business models to promote their application. But as with all new markets there are limitations such as systems fuel requirements, delivery, and storage issues.

Common sources of woody biomass include whole tree harvest (chips or roundwood), timber harvest residue (e.g. bole chips), mill residue (chips and sawdust), used "ground" pallets, pellets, construction and demolition debris, and dedicated short rotation woody crops (e.g., hybrid poplars and willows) usually cultivated using agricultural practices. Much of the immediate opportunity for wood fuel in the region comes from the timber harvest residues—these residues can include small diameter logs, branches and limbs, bark, needles, and stumps. Typically, logging residues can make up about 25–45 % of the tree's biomass when trees are harvested for sawtimber or pulpwood. Much of the harvesting that occurs in the Northeast, especially unsustainable "high grades" leaves large amounts of logging residues as well as small-diameter or low-value trees.

In some cases loggers are harvesting whole trees and chipping them. Most commonly, chips are usually made from the tops, branches, and nonmerchantable parts of the tree. These are by-products after the logger sets aside the higher valued sawlogs and veneer. Often this biomass is chipped at the landing and sent directly to the processing facility. Some of the logging residues are used in pulp markets, but in areas where the demand for pulpwood has decreased, bioenergy can provide a valuable market for this material. Chapter 3 discusses the availability and potential for biomass from integrated forest operations in the region.

Mill residues are the wood that remains after boards and other wood products are manufactured. This includes sawdust as well as chips or shavings ("slab wood" is not as common anymore). This wood is usually dryer than whole tree chips, and sawdust may be useful only in certain fuel handling systems. Pellets from sawdust have become one of the fastest growing biomass markets, both for domestic use and for the relatively new and expanding export market worldwide. Chapter 9 discusses the history and development of the pellet market in the region. Although they are more expensive than wood chips or roundwood, important benefits of pellets are the ease of handling and the consistency of size and moisture content. These systems are discussed more fully in Chaps. 7 and 8. Construction and municipal waste, another important source of woody biomass, is plentiful in the region, especially in urbanizing areas where disposal costs make it an inexpensive fuel source but also a concern in terms of toxics and impurities.

One of the main drivers of wood energy in the region is the lower fuel price as compared to fossil fuels, particularly in thermal systems. Although the market for woody biomass is still young, it parallels that of the pulp wood markets. Some areas have competitive markets, especially where pulp markets are active. Prices are highly localized and depend primarily on harvesting and transportation costs. Factors influencing price include geography, delivery method, and transportation network. Chapter 3 discusses the economic models of feedstock availability across the region. Another economic consideration is the fragmented supply chain from the landowner to the end user that includes the forester, the loggers, the truckers, and the processors. Developing an efficient, effective supply chain is an important challenge facing the industry at present.

On the societal side, wood energy in the region requires dealing with landowners who often think mainly about nontimber benefits, and need convincing that biomass harvests can be a sustainable component of responsible forest stewardship. On the other hand, when profit is a major consideration, one finds that prices for biomass (on the stump) are often very low. To make the biomass profitable its harvest must usually be coordinated with other highly valued timber removals to sway a landowner to sell biomass. One interesting factor that has arisen recently in the region is the newfound abundant supply of shale-deposit natural gas. It remains to be seen how this local energy boom will affect landowner perspectives and interest in renewable energy. Chapter 12 discusses some of these social considerations.

There are also health and environmental concerns related to the use of wood for energy. The top health issue is undoubtedly concern about air emissions, especially particulate matter, from burning biomass for heat, which is discussed in Chap. 11.

The key environmental issue revolves around proper forest management to ensure sustained long-term site productivity. Harvesting biomass for energy could impact soil nutrients, organic matter and soil moisture-holding capacity. Nitrogen and other essential plant elements are abundant in twigs and foliage so that harvesting all above-ground biomass could theoretically remove a large proportion of nutrients. Several states in the northeast have developed Forestry Best Management Practices (BMPs) for biomass harvesting guidelines to address these concerns. This is discussed more in Chap. 2. Lastly, the complex question of carbon emissions and wood energy is an area of interest for policy developers that must be addressed if our picture of wood energy is to be complete (see Chap. 4). Interestingly enough, health and environmental concerns tend to be largely dependent on how wood energy is implemented, rather than if it is implemented—methods and technologies are expected to have a great effect on how wood energy impacts the regional ecosystem.

Finally, a biomass project requires financing and dealing with risk. Perhaps the key risk is ensuring constant and stable supply of feedstock. Although it is well recognized that most of our region has plentiful supplies of wood, availability, cost, and intangibles, such as transportation costs, are an issue. Making sure one has enough suppliers, solid contracts with suppliers, enough storage capacity in the event of shortfalls, adds costs but also mitigates risk. Economic questions are dealt with throughout the book, especially in Chap. 3, whereas Chap. 13 discusses financing.

The following is a short synopsis of each chapter.

*Chapter 2* sets the stage and context for developing wood-based bioenergy projects in the Northeast. The authors describe the forest condition, extent of wood in the region, and lay out some issues and constraints to wood energy development. The region is relatively large and forests are diverse. Almost three quarters of the forest are in 4 of the 12 states in this region. Given the diverse forest types one finds a varied forest products industry. Generally the region's industry specializes in high-quality saw and veneer wood products. Maine is an exception with its very strong pulp market. Understanding the current wood product market is critical to bioenergy development since a key question is how wood for bioenergy complements or competes with other forest products.

Local considerations in project development are critical. Since wood energy is sourced locally it takes pressure off the need to rely on imported supplies. However, this creates its own issues with respect to local regulations and environmental impacts. Chapter 2 explains how state and even local policies have evolved to address harvesting guidelines for wood energy.

The region has abundant supplies of low-use wood and the forests have a positive tree volume growth-to-drain (removal) ratio. However, as Chap. 2 discusses, perhaps the biggest question in the Northeast is how much biomass is there that is practically available? The region is heavily populated with 21 % of the country's population and only 6 % of the land area. On the one hand the high population and urban areas make for high energy demands (currently mainly in the form of coal and nuclear) but from which biomass could contribute. On the other hand, population pressures lead to urbanization/deforestation and forest fragmentation. The forests in our region are already highly fragmented with millions of private landowners owning small forested parcels. Developing bioenergy projects will require working with these landowners who in many cases prefer esthetic, wildlife and other amenities to harvesting timber.

*Chapter 3* addresses the key economic questions of feedstock supply availability and at what price. The chapter shows results from agricultural simulation models that project supplies by 2030 given a variety of farmgate prices for the Northeast region. Key to any question of availability are production costs and competition from alternative markets. The manner in which supply changes with price allows policy makers and producers determine feasibility of alternative opportunities. The models are based on the Department of Energy's Billion Ton Report Update of 2011. The two main sources of woody feedstock in the region are projected to be forest resources - such as, thinnings (thinnings and logging residues), and short rotation woody crops (SRWC). The SRWC comes from nonforested land and the paper explains assumptions for which land is available for SRWC versus other agricultural crops and pasture. Baseline projections suggest an increase in biomass production from a current 4.3 dry million tons at $22 per ton over 25 million tons at $88 per ton in 2030. SRWC will become a significant component of the feedstock by 2020. The model estimates in 2020 at a price of $66 per ton, there will be about 13 million tons of woody biomass available in the Northeast of which 7.5 comes from SRWC. Most of the material will initially come from forest rich states such as Maine, Pennsylvania, and West Virginia while SRWC will come from agriculture rich states such as New York and Pennsylvania.

*Chapter 4* builds on the ecological issues raised in Chap. 2 but focuses on carbon. Harvesting woody biomass will have significant impacts on forest carbon stocks and flows. It is clear that our northern forests as a whole are a carbon sink (growth exceeds removals and mortality). But there are important questions as we ramp up production of bioenergy. What will happen to forest carbon levels in the event of increased biomass harvesting? How much can we increase harvest while maintaining stable sequestration rates? Using stochastic models this chapter addresses these questions. It first describes forest carbon dynamics, mainly due to harvesting. Even setting a "baseline" level of carbon storage is very controversial. Although northern forests are currently net carbon sinks it is not a given it will remain that way, even without biomass harvests. However, carrying out "business as usual" harvest regimes could see a concomitant increase in sequestration since we mostly carry out partial cuts. However increasing harvest levels could have negative implications for carbon levels in forests. Modeling, of course is fraught with assumptions and the author points out that forest dynamics are not "inherently steady state." The chapter also discusses implications for net carbon impacts taking into account offset from reduced fossil fuel use.

*Chapter 5* discusses the state of tree improvement and breeding both for forest trees and short rotation woody crops (focusing on willow and hybrid poplar). For viable bioenergy production across the supply chain, perhaps the most important factor is consistently high yields of biomass. The key goal of breeding is to increase yields, especially on marginal lands, but other traits are also examined depending on the end use, such as resistance to pests and diseases. Depending on the end use, traits can be bred for high energy/lignin content for thermal applications or high cellulose/sugar content for liquid biofuels. Due to the long rotation ages of forest trees the focus of current research is on SRWC, where new improved cultivars can be bred in terms of years instead of decades. The chapter discusses all the relevant and latest tools and techniques from traditional breeding to genomics and genetic engineering.

*Chapter 6* addresses the issue of optimizing biomass harvest systems. Harvest systems include the processes used to fell and collect trees and transport them to the processing facility. The success of a bioenergy project can hinge on selecting harvest systems that are both financially and environmentally effective. The chapter discusses productivity and costs of various harvesting systems and provides a detailed overview of the variety of harvesting systems from "wood energy bundlers" to "coppice headers." This chapter is especially useful to practitioners and researchers in showing how to measure harvest productivity and its associated costs. This ranges from basic "time and motion" measurements to integrated Global Positioning Systems (GPS) approaches. The types, uses, and pros and cons of using economic models to analyze component costs of the harvesting systems are also discussed. One key lesson is that increased harvest efficiency must be weighed against potential site impacts such as future productivity and environmental degradation. Finally, the chapter lays out a variety of scenarios showing how delivered costs vary for different harvesting and transportation systems.

*Chapter 7* focuses on wood used in residential heat. Many take this sector of woody heat for granted, but it plays an essential role in future development of biomass markets. The most common use of wood biomass in Northeast is for heating homes. Over one-half million homes in the Northeast use wood heat and there seems to be a renewed interest as the costs of alternative fuels increase and improved and more efficient stoves emerge on the market. For many homes it comes down to tradeoff between cost savings with wood versus oil (or other fossil fuels) and the convenience factor, i.e., not having to deal with storage and handling issues. Wood fuel's cost is the least expensive on a gigajoule (GJ) basis and least volatile in terms of price fluctuations. The authors discuss the history and use of wood heat in the Northeast, noting its decline since the advent of fossil fuels in the late 1800s. The chapter details the types and technologies of different burning devices. In recent years, the industry has responded to development of new technologies and tightening of EPA regulations, making stoves much cleaner and more efficient. Different types of wood stoves, pellet stoves and outdoor boilers are options for homes. For example, pellet stoves are more efficient and consume less wood compared to other devices. The authors end their chapter by discussing prospects for wood heat in the future, which basically comes down to tradeoffs in cost of other fuels, health issues, and convenience.

*Chapter 8* looks at the commercial side of heat and electricity from woody biomass. Although wood heat for homes is most common, there is growing interest in replacing institutional oil boilers with wood boilers to save on fuel costs. As a result schools, office buildings, hospitals, and manufacturing plants are examples of places where wood heat and even Combined Heat and Power (CHP) systems can work economically. The chapter describes the different type of system configurations from fuel storage and handling to combustion design and emission controls. System design varies quite widely and it is important especially with respect to type of and quality of woody fuel used. If electricity production is a consideration, the type of generator is an important consideration. Key issues are automation of the system, type of fuel, and installation costs. Retrofitting existing facilities can be costly. Determining payback and financial returns of a project is important as these costs, as the authors say can “creep” up. Perhaps the most important part of designing a project is ensuring good system performance from whatever design is selected. Performance implies factors such as thermal and electrical efficiency (how much fuel is actually available for heat for electricity) and emissions performance. Finally the chapter discusses emerging technologies such as gasification and Organic Rankine Cycle systems.

*Chapter 9* presents a historical perspective of the pellet market in the Northeast. Written by one of the early developers of the market, its reads like a biography of sorts. Scattered throughout are great anecdotes about the nascent and early days of wood pellet production. Traditional wood energy has been around a long time but it is pellets are more recent and beginning to influence the market. The early days saw wood stove proliferation after the 1973 oil embargo, only to be followed by EPA standards dramatically reducing the number of wood stove manufacturers. However pellet stoves, because of their high air-to-fuel ratio were exempt and so the rest is history. What’s interesting is that the first markets on the east coast were mainly for institutional and industrial customers, whereas today the residential market dominates. Over the years there were many ups and downs in the pellet market with competition coming from gas stoves, low oil prices, and pellet storage shortages where demand exceed supply. New capacity was installed after hurricane Katrina, but in the last few years millions of tons of new capacity are being built for export to Europe. However, the US market is also rapidly developing as the pellet fuel industry is becoming certified and commercial, and institutional-type consumers are realizing the fuel savings from central heat, using pellets delivered in bulk, which the author suggests will soon outpace and dwarf the current bag market.

*Chapter 10* focuses on methods for converting wood to liquid fuels. This of course is of particular interest given the potential carbon emission reductions and associated benefits of replacing fossil fuels. The chapter considers all the available platforms for converting wood to liquids. The state of liquid biofuels is at the cusp of commercial production and it is timely to look at what methods are suited to different woody feedstocks. The technologies and science are quite complex but the authors lay out a concise, orderly description of the methods. The authors discuss mainly sugar (hydrolysis and fermentation) and pyrolysis platforms but mention briefly gasification and other platforms such as carboxylate platforms. For each platform the authors provide detailed information about the method of feedstock conversion, pretreatment (if needed), the type product (i.e., ethanol, and drop in fuels) and which forest resources are most applicable or preferred to that particular method/platform. Key issues also include conversion costs, access and availability of resources, and technological limitations. One important caveat is that the scale of the processing facility is limited by resource availability, and even the largest corn ethanol facility is an order of magnitude smaller than an average oil refinery (400 million liters per year vs. 6.8 billion liters per year). It is interesting to note that a 400 million liter (~100 million gallon) per year biorefinery corresponds to the largest commercial pulp mills, with a capacity of 3,000 dry tonnes/day of wood delivered.

*Chapter 11* provides a succinct summary of the knowledge about wood combustion emissions and impacts on health. The authors focus on nonresidential scale facilities such as schools and hospitals (see Chap. 8). The chapter first looks at the evidence of exposure to emissions. The EPA lists over 100 chemical pollutants in wood combustion emissions. Of major concern is particulate matter, especially particles less than 2.5 μm in size. Other important pollutants are carbon monoxide, and polycyclic aromatic hydrocarbons. Key issues for examining pollutants and their health impact are the type of fuel used, the moisture content, the combustion technology, how the system is operated, and the emission controls used. Each of these five issues is clearly discussed and elaborated in the chapter. The evidence linking health concerns and the types of populations more at risk is discussed. Specific information needed to make decisions about health impacts from wood burning emissions is noted which leads to a discussion on policy issues and recommendations for protecting public health. The authors focus on air-quality regulations and roles of states and EPA in setting requirements. Recommendations include providing incentives for cleaner burning systems, more research into health impacts, and consistent and standardized regulations across the region.

*Chapter 12* provides insight into an important cog in the biomass wheel, the social issues. Most of the book deals with economic- and engineering-type issues, but for biomass to grow, understanding societal concerns from using biomass for energy must be addressed. The chapter focuses on ways we can take the science of bioenergy and link it to practice to meet social needs. The authors call it "knowledge to action" where the researcher's knowledge and "supply" is matched with the stakeholders "demand." Stakeholders include landowners, communities, industry, and government. The paper assesses stakeholder's needs and knowledge about the emerging bioenergy sector in the Northeast. They examine barriers, opportunities, and research needs by interviewing a diverse set of people involved in the bioenergy sector. Key barriers include economic issues and public perception of the industry. Key opportunities and needs are developing sociocultural capacity, especially with growers and landowners and developing viable feedstock production and processing systems that are sustainable. Significant points emerging from this survey of stakeholders is the importance of interdisciplinary approaches, the need for early identification of issues, ability to be adaptive as the project develops, and for trustful collaboration. As one the interviewees stated, the biomass and technology is available, the key is "showing people that it can be done sustainably and moving forward."

*Chapter 13*, the final chapter, although the author suggests that it is the first step not the final step, is all about financing biomass projects. That is true—without a clear, solid, and doable financial plan and its implementation—the project will go nowhere fast. It may sound simple i.e., raising capital and using cash flow to pay off debt, but it is far from that. Focusing on project finance, as opposed to corporate finance, the paper delves into really critical issues and decisions any biomass project needs to consider. What is important is the financing process which includes the project structure, its documents, and how to attract financing. Project agreements, of which there are many, include consents and contracts, which are the legal foundation of the project. Then there is due diligence to ensure that the investor will finance a project, including a package that supports and justifies the project. The variety of loan types is another area which requires some thought since many biomass projects are unproven hence needing unique approaches to garner finance. The chapter clearly explains all the factors to consider and ends with some unique things relative to a biomass project, which include ensuring an ample supply of feedstock, addressing any environment-related issues with sourcing feedstock, and making sure the project is performing to specifications after construction. Accounting for unexpected and usually rising costs over the life of the biomass project for operation and maintenance is also a crucial consideration in financial planning.

The editors gratefully acknowledge the hard work and dedication of the many authors who contributed to this volume and look forward to the continued work that is being done in this important area. We also like to acknowledge the Northeast Woody/Warm-season Biomass Consortium (NEWBio) project funded by the USDA-NIFA. It is our sincere wish that this book will contribute to the better understanding of, appropriate use, and wise care of the outstanding forests that we are fortunate to have in this region.

# Chapter 2
# Forestry in the Northeast

**Alexander M. Evans and Robert T. Perschel**

## 2.1 The State of Forests in the Northeast

Forests are the dominant land use in the Northeast United States, and as such are of significant interest as a source of fuel to meet energy needs in a sustainable, renewable manner. Unlike fossil fuels which are often shipped thousands of miles from source to use, the production of forest bioenergy is often a much more local concern. The biogeographic setting determines growth rates and in turn the sustainable supply of a feedstock. Local and regional economics have a greater influence on forest biomass prices than do the global markets which dictate the prices of fossil fuels such as oil. Local climate influences the quantity and type of bioenergy best suited for heating and cooling applications. Even at the policy level, a patchwork of municipal and state policies promotes, retards, or regulates forest bioenergy. This chapter provides an introduction to the ecological, social, and economic context for forest bioenergy in the Northeast.

### *2.1.1 Geography of the Forests in the Northeast*

There are numerous ways to delineate the northeast region of the United States, from ecological zones to administrative boundaries. Here our goal is to describe an area that is similar enough in ecological, social, and economic dimensions to permit generalizations but also large enough to allow for regional relevance. Nearly all

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M. Jacobson and D. Ciolkosz (eds.), *Wood-Based Energy in the Northern Forests*,
DOI 10.1007/978-1-4614-9478-2_2, 

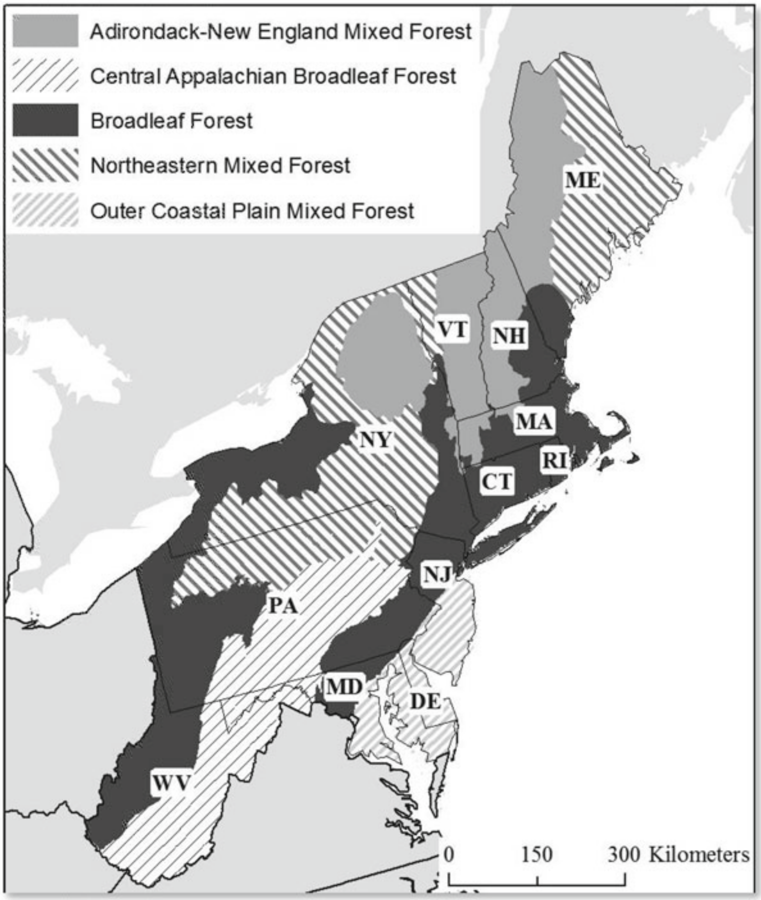


**Fig. 2.1** Map of northeast states and forests within the northeast ecological provinces

definitions of the Northeast include the six New England states: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut. The US Environmental Protection Agency's region 1 includes only the New England states, while the Natural Resource Conservation Service has a more expansive Northeast region. Importantly for discussions of carbon and climate change, the New England states are joined by New York, Pennsylvania, Delaware, Maryland, and New Jersey in the Northeast Regional Greenhouse Gas Initiative (RGGI). Where possible our administrative definition of the Northeast follows the US Forest Service's definition of the Northeast which includes the six New England states, New York, Delaware, Maryland, New Jersey, and West Virginia (Fig. 2.1).

Beyond state boundaries, delineating ecological boundaries is no less difficult. Using the US Department of Agriculture's ecological provinces the Northeast region encompasses four ecological provinces including Northeastern mixed forest, Adirondack-New England mixed forest-coniferous forest, Eastern broadleaf forest, and Central Appalachian broadleaf forest (McNab et al. 2007). Based on the similarity of forest types this discussion is relevant to forests as far south as Georgia and as far west as Minnesota.

### *2.1.2 Climatic and Physiographic Setting*

The Northeast's climatic and physiographic setting drives forest processes and composition. Over the last century, the average annual temperature in the Northeast was 8 °C (46 °F). The winter temperatures average was −4.3 °C (24 °F) while summer temperatures average was 19.6 °C (67 °F) (National Climate Data Center 2012). The prevailing wind direction, from west to east, creates a continental climate except for coastal areas moderated by the Atlantic Ocean (Barrett 1980a). On average over the past century, the region received 104 cm (41 in.) of precipitation which tended to be evenly distributed throughout the year (National Climate Data Center 2012). However, the Northeast is becoming hotter and wetter (Hayhoe et al. 2008). The largest temperature increases have come during the winter, which has warmed at a rate of 0.70 °C (1.3 °F) per decade over the last 35 years (Hayhoe et al. 2007). In the Northeast, the average annual precipitation has increased by 9.5 mm (0.4 in.) over the last century (Easterling 2002, Hayhoe et al. 2007). Very heavy daily precipitation has also increased in the last century (Easterling 2002), and the decrease in the percent of precipitation the Northeast receives as snow has been most notable in northern and coastal areas (Huntington et al. 2004).

The tallest mountain in the Northeast is New Hampshire's Mount Washington at 1,917 m (6,288 ft), but much of the region is set on upland plateaus between 150 and 460 m (500 and 1,500 ft). The Appalachian Mountains are geologically complex and run through the Northeast, including the Longfellow Mountains of Maine, White Mountains of New Hampshire, the Green Mountains of Vermont, the Adirondack and Taconic Mountains of New York, and the Alleghany Plateau region of Pennsylvania and West Virginia. An eastward extension of the Allegheny Plateau forms the Catskill Mountains of New York, while south and east of the plateau, extensive compressional folding of the bedrock is responsible for the complex ridge and valley topography of central Pennsylvania and eastern West Virginia. The region's main rivers, including the Susquehanna, Potomac, Delaware, Hudson, Connecticut, Merrimack, Kennebec, and Penobscot, form wide valleys separating these highlands. The Ohio River and its tributaries cross West Virginia and western Pennsylvania from the headwaters in the Alleghany Mountains.

The Laurentide Ice Sheet covered most of the region until about 12,000 years before the present and left rocky moraines, glacial erratics, kettle ponds, and deep till soils as it retreated. Glaciation created young soils which vary considerably across small spatial scales. The soils of much of the northern portion of the Northeast (Adirondacks, White and Green Mountains, and Maine) are spodosols, acidic and infertile. Inceptisols (young, more fertile soils) dominate much of the southern New

England and southern New York. The Laurentide Ice Sheet never reached southern Pennsylvania, West Virginia, southern New Jersey, Maryland, or Delaware, so in this southern portion of the region there is a higher percentage of older soils. The ultisols found here are old and strongly weathered, but in some locations such as the piedmont region of Maryland and south-central Pennsylvania they are often deep and highly productive.

### *2.1.3 Forest Types*

Major forest types in the region are spruce-fir (*Picea sp.—Abies sp.*), northern hardwood (Eyre 1980), oak-hickory (*Quercus sp.—Carya sp.*) or transitional hardwood forests, and the mixed-mesophytic forests. Spruce-fir forests dominate the inland areas of Maine as well as the mountain tops of the northernmost portions of New York, New Hampshire, and Vermont. Remnant spruce-fir forests can also be found on the mountain tops south into West Virginia. Northern hardwood forests are dominated by maple (*Acer sp.*), beech (*Fagus grandifolia)*, and birch (*Betula sp.*) and cover lower elevations and southern portions of Maine, New York, New Hampshire, Vermont, and the northern portion of Pennsylvania. Northern hardwood forests also include conifers, e.g., hemlock (*Tsuga canadensis*) and white pine (*Pinus strobus*), in the mixture (Westveld 1956). The oak-hickory forests are the transitional forest type between the northern hardwood forests type and the mixed mesophytic forest that dominate further south (Westveld 1956). Oak-hickory forests are found on the glaciated inceptisols of southern New England and include a mix of species from the north such as birches, beech, and maples and those from the south such as hickories, ash, and tulip poplar. The inter-mixing of species becomes even more pronounced in the mixed mesophytic forests further to the south. Because these forests acted as a refuge during the last glaciation and because of the great variation in topography, the mixed mesophytic forests are some of the most biologically diverse temperate regions of the world (Loucks et al. 1999). Mixed mesophytic forests contain a variety of magnolias, oaks, hickories, elms, birches, ashes, basswood, maples, black locust, pines, black walnut, tulip-poplar, blackgum, hemlocks, black cherry, and beech.

Of course there are many forest stands that do not fit perfectly within the major forest types described above. For example, pine-dominated forests are found in the coastal areas of Maine and New Hampshire and much of central Massachusetts. These pine forests tend to occupy sites with coarse-textured, well-drained soils (Barrett 1980a). There are also rare forest types that have become the focus of conservation efforts such as white-cedar (*Chamaecyparis thyoides*) swamps. While many of these rare forest types are protected from harvesting, biomass removals for energy may be a crucial restoration tool in fire adapted communities. For instance, pine barrens, forests dominated by fire adapted pitch pine (*Pinus rigida*), may need to have trees removed as the first step in the restoration process. Because humans have reduced the frequency of fire in these forests, more trees have grown up and

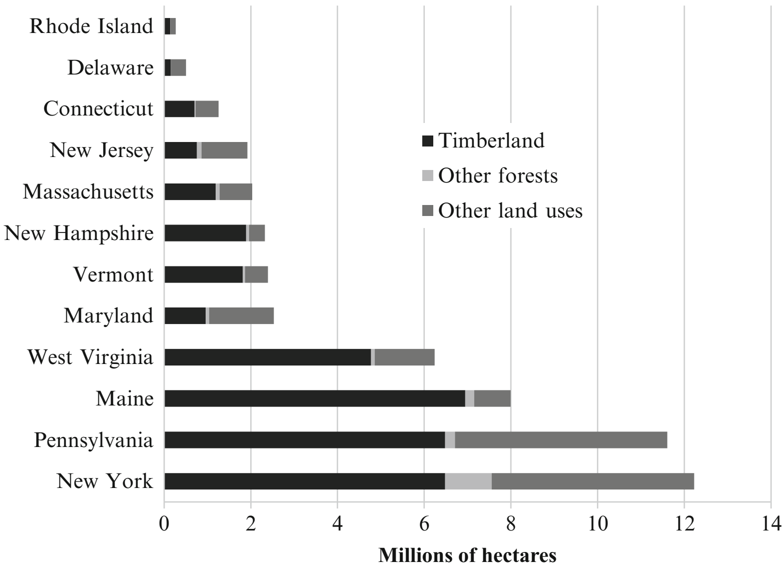


**Fig. 2.2** Land cover by state from Smith et al. 2009

they have become unnaturally dense or converted to a closed canopy forest type. Biomass needs to be removed to reduce fuel loads in an effort to protect human life and property, and to perpetuate fire-dependent pine barrens ecological communities (Jordan et al. 2003, Brose and Waldrop 2006). The largest areas of pine barrens are in New Jersey and southeastern New York, but there are discontinuous examples of the forest type on outwash fans and dry ridgetops throughout the region.

### 2.1.4 *Forestry and Forest Products in the Northeast*

The Northeast has about 34 million hectares of forests (84 million acres) or about 67 % of the total land area (Smith et al. 2009). Northern states, particularly New Hampshire and Maine, have a greater percentage of land in forest (84 and 89 % respectively) than states with higher population densities such as Delaware which is only 31 % forested (Fig. 2.2). The vast majority, 94 %, of the forest land in the Northeast is timberland, areas where commercial timber could be produced. Reserve forests are a tiny percentage of the landscape except in New York where the Adirondack Park excludes 13 % of the state's forests from harvesting. Similarly, planted forests make up a very small percentage of the timberlands (3 %) in the Northeast in contrast with other regions such as the Southeast where 25 % of timberlands are planted forest (Smith et al. 2009).

About half of the timberland in the Northeast can produce at least 3.5 cubic meter per hectare per year (50 $ft^3$/ac/year) while the rest of the timberland is less

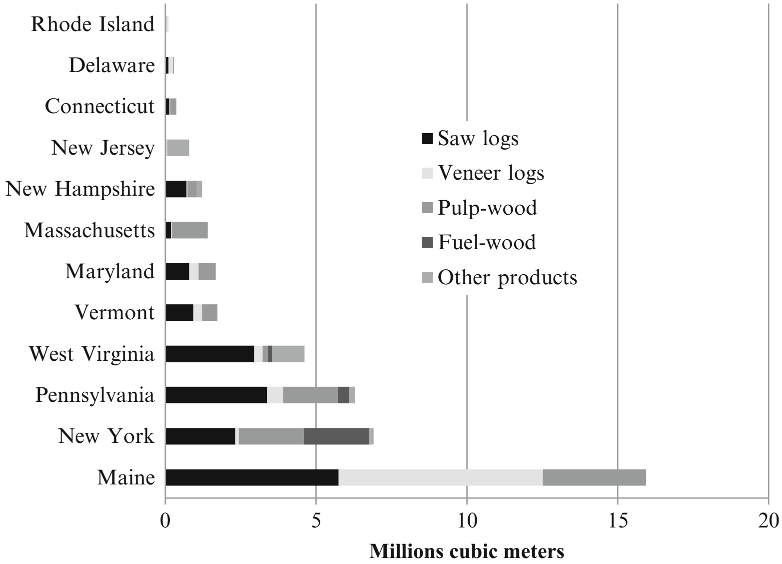


**Fig. 2.3** Wood products from the Northeast in 2006 from Shifley et al. 2012

productive (Smith et al. 2009). Maine and West Virginia are the only states with more than a million hectares of timberland than can produce at least 5.9 cubic meter per hectare per year (85 ft³/ac/year). A little over half of the timberland in the Northeast is between 40 and 80 years old and notably, only 6 % is over 100 years old (Smith et al. 2009). However, a recent analysis highlights the difficulty of assigning a single age in forests that are often partially harvested (Canham et al. 2013). Much of the region is comprised of second- or third-growth forest that is yet to reach late seral stages (Irland 1999). Uneven-aged forests make up only 4 % of Northeast timberlands or about 1.4 million hectares (3.5 million acres). The majority of uneven-aged stands are in the Northern hardwoods forests. About 6 % (or 735,000 ha [1,818,00 ac]) of Northern hardwood forests are uneven aged (Smith et al. 2009). Northern hardwoods are well suited to uneven-aged management because many of the commercially important species are shade tolerant.

In the Northeast, net annual growth of growing stock on timber land was 92 million and 33 million cubic meters were harvested in 2006 (Smith et al. 2009). Hardwoods made up 74 % of the growth and 68 % of the harvest in 2006. Of the 33 million cubic meters harvested in 2006, 95 % came from private lands (Smith et al. 2009). In 2006 the Northeast produced about 10 % of the total U.S. roundwood products, but about 25 % of the veneer (Fig. 2.3). Maine has the largest production of sawlogs (5.7 million cubic meters, 203 million cubic feet), veneer (6.8 million cubic meters, 239 million cubic feet), and pulp wood (3.4 million cubic meters, 121 cubic feet). The next largest producer, New York, produced about a third of Maine's volumes (Shifley et al. 2012). About 2.7 million cubic meters of fuel wood, a category particularly relevant to bioenergy production, was produced in the Northeast in 2006 (Shifley et al. 2012). Reports on forest products are beginning to report biomass chip or bioenergy harvests. For example in Maine, biomass chip harvests increased from 0.9 to 2.7 million cubic meters (0.4–1.2 million cords) between 2000 and 2008 (McCaskill et al. 2011). In 2009, the Northeast accounted for about 24 % of the wood pellet production capacity or about 1 million metric tons (Spelter and Toth 2009). In the Lake States the increase in demand from pellet manufacturers is beginning to replace declining demand for lower-quality roundwood from the paper industry (Luppold et al. 2011). Another important product from a bioenergy perspective that can be lost in national harvest assessments is landowner-harvested firewood. In the Northeast about 34 % of family forest owners say they harvest firewood from their property (Roper Public Affairs 2006).

Based on a recent study, the median size of woodshed for softwood and hardwood mills in the Northern New England are about 4,200 and 8,700 $km^2$ (1,600 and 3,400 $mi^2$) respectively (Anderson et al. 2011). Areas of high hardwood procurement pressure based on the overlapping woodsheds for existing mills was highest in Herkimer County, New York, central Vermont, and western Maine. In contrast, the same analysis suggests that the areas of greatest softwood procurement pressure were Somerset and Piscataquis counties, north of Moosehead Lake in Maine with significant but light pressure in northern and southwestern New Hampshire (Anderson et al. 2011).

### *2.1.5 Land Ownership, Conservation, and Fragmentation*

Eighty percent of the 34 million hectares of forest land in the Northeast is privately owned (Fig. 2.4). The percentage of private ownership is greatest in Maine (94 %) and is lowest in New Jersey (62 %) and Pennsylvania (71 %). The high percentage of private ownership in Maine is due to a large corporate timber base (over four million hectares [ten million acres]) (Smith et al. 2009). The ownership of forest land in the Northeast has changed significantly in recent decades. One trend has been turnover of land forest holding in the Northern Forest, where 23 million acres were involved in land sales between 1980 and 2005 (Daigle et al. 2012). The change in ownership has generally involved a divestment of timber or wood products companies and an increase in the forest holding of Timber Investment Management Organizations (TIMOs), Real Estate Investment Trusts (REITs), and land trusts. The change in ownership from wood products companies to TIMOs and REITs means that management and silvicultural decisions are not as directly tied to mills' needs. The ownership change also increases the potential for greater land ownership turnover and forest fragmentation. However a recent report from North Carolina highlights how TIMOs and REITs can act as partners in protecting forest land and preserving working landscapes (Weinberg 2012).

On average, forest land owners in the Northeast own about 10 ha (26 acres), but in Southern New England and the mid-Atlantic states the average forest ownership is