NATURAL CAPITAL INITIATIVE AT MANOMET REPORT

BIOMASS SUSTAINABILITY AND CARBON POLICY STUDY

APPENDICES

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APPENDIX 1-A

FEDERAL, STATE AND REGIONAL BIOMASS ENERGY POLICIES

The following summary of federal and select state policies and incentives related to the development of biomass energy facilities addresses the following areas:

- A summary of relevant federal policies affecting the development of biomass energy;
- A review of relevant regional policies and regulatory initiatives impacting the development of biomass energy;
- A summary of current policies in the State of Massachusetts that relate to renewable energy and biomass facilities as well as state policies related to sustainable forestry issues; and
- A review of notable biomass policies and incentives in other states, with a particular focus on renewable energy, forest sustainability, carbon regulation, and climate change issues.

The information presented here is drawn from several sources including work prepared for the Biomass Energy Resources Center by Shems Dunkiel Raubvogel & Saunders PLLC, research conducted by Charles Niebling of New England Wood Pellet, analysis conducted by the Biomass Thermal Energy Council, analysis conducted by Jesse Caputo of the Environmental and Energy Study Institute, and analysis provided by the Pinchot Institute for Conservation.

This discussion includes a historical review of prior federal policies under the Public Utility Regulatory Policy Act of 1978 (PURPA), which spurred development of many existing biomass energy facilities in the U.S.

I. Federal Policies & Incentives Relevant to Biomass

Federal incentives for renewable energy (including biomass) have taken many forms over the past four decades. The focus of most of these programs has been on encouraging renewable electricity generation and, more recently, production of renewable transportation fuels, such as ethanol with little attention to or investment in the thermal energy sector. Consequently, biomass as an energy source is being primarily directed into the large scale production of liquid biofuels and/or large scale electric generation. In addition, existing renewable energy policy provides little or no connection to efficiency requirements, sustainable forestry provisions or carbon sequestration goals.

As discussed below, federal policy initially focused on encouraging renewable electricity generation by requiring utilities to purchase electricity from renewable energy generators at a fixed cost through the Public Utility Regulatory Policy Act (PURPA).

More recently, federal policy has shifted towards encouraging renewable energy through tax incentives and direct grants—with the primary focus on renewable transportation fuels and renewable electricity generation.

A. Historical Review of Major Federal Policies Incentivizing Biomass Development

Development of biomass energy facilities in the U.S. in the last four decades has been largely driven by federal energy policies and incentives designed to encourage renewable energy development and diversification of energy sources. Historically speaking, the most important of these federal policies was the Public Utility Regulatory Policy Act (PURPA). PURPA was passed in 1978, primarily in response to the sharp spike in oil prices during the 1970s, and embodied a national effort to reduce reliance on foreign oil and diversify domestic energy generation.

To achieve these goals, PURPA contained several provisions specifically designed to spur development of renewable energy generation in the U.S. Chief among these provisions was the requirement that utilities purchase the power output from certain small renewable energy generators—known as "qualified facilities" (QF)—at the utility's "avoided cost." The certainty of these guaranteed, highly favorable rates led to a dramatic increase in renewable energy generation, including an estimated three-fold increase in biomass facilities in the 1980s and early 1990s.

But the spike in biomass facilities developed under PURPA was relatively short lived and market conditions and regulatory changes have limited the value and application of the "avoided cost" provisions of PURPA. Deregulation efforts in the 1990s also led to increased competition among energy generators in many parts of the U.S., opening the grid to a greater number of small or independent power producers. Due to the perceived increase in competition in power markets, Congress revised PURPA in 2005 and, combined with subsequent regulator action, PURPA no longer serves as a significant incentive for the development of biomass facilities in the US.

B. Current Federal Policies Related to Biomass Energy Development

Current federal policies and incentives for renewable energy facilities take many different forms. This review focuses on incentives relevant to biomass power or combined heat and power vs. the production of liquid biofuels, which is beyond the scope of this project. These incentives have moved away from the "guaranteed cost" approach implemented under PURPA, and now rely primarily on either (1) federal tax incentives, or (2) direct federal grants or loans from federal agencies. Specific examples of these two types of incentives are summarized below.

Federal Tax Incentives

Overall, existing federal tax incentives for renewable energy focus on electric power generation and the production of liquid biofuels. Consequently, biomass feedstocks are being directed preferentially towards these types of energy applications. In addition, existing federal tax incentives provide little or no connection to efficiency requirements, sustainable forestry provisions or carbon sequestration goals.

1. Production Tax Credit (IRS Code Section 45)

The Renewable Energy Production Tax Credit (PTC) provides a tax credit for owners or operators of qualifying renewable electric generation facilities for the first ten years of operation. Qualifying resources include both "closed-loop biomass" and "open loop biomass" facilities that sell power to the public. Co-fired units (those burning both fossil fuel and biomass) are not eligible. The 2009 American Recovery and Reinvestment Act recently extended the PTC for projects placed into service from the end of 2010 through the end of 2013. The benefit of this production tax credit can only be realized by an entity with sufficient taxable income to take advantage of the credit; the PTC will not provide an incentive to entities that do not pay federal taxes unless they partner with other entities with federal tax exposure. This program is not subject to annual appropriations, but does need to be extended every year.

2. Business Energy Investment Tax Credit (IRS Code Section 48)

The Business Energy Investment Tax Credit (ITC) provides a credit based on the value of the investment in certain types of electrical generation and combined heat and power (CHP) biomass facilities and was also recently expanded to apply to general closed and open loop biomass facilities. The CHP ITC is a 10 percent tax credit for the first 15MW of a system up to 50MW. The CHP ITC extends through December 31, 2016. The 2009 ARRA also expanded the availability of the ITC to other closed loop and open loop biomass facilities (besides CHPs) that are otherwise eligible for the PTC. Under this new provision, the owner of a biomass facility that qualifies for the PTC may elect to claim an ITC in lieu of the PTC.

3. Grant in Lieu of Investment Tax Credit

The 2009 ARRA also created a new program that allows taxpayers eligible for the ITC to elect to receive a grant from the U.S. Treasury. This is technically a direct federal grant, not a tax credit, but is covered here for sake of continuity with the related ITC and PTC provisions. This cash grant may be taken in lieu of the federal business energy investment tax credit (ITC). Eligible CHP property includes systems up to 50 MW in capacity that exceed 60 percent energy efficiency. The efficiency requirement does not apply to CHP systems that use biomass for at least 90 percent of the system's energy source.

4. Clean Renewable Energy Bonds (CREBs) (IRS Code Section 54)

The Clean Renewable Energy Bonds (CREBs) program was created by the Energy Policy Act of 2005. The program provides "tax-credit" bonds to renewable energy projects developed by governments or electric coops. The bonds are awarded to eligible entities on a competitive basis by the IRS. Both closed-loop and open-loop biomass facilities are eligible for the program. Unlike typical bonds, which pay interest to the bondholder, the tax-credit bonds provide bondholders a credit against their federal income tax, effectively providing the issuer of the bonds a 0% loan with the federal treasury covering the interest payments. The 2009 ARRA allocated an additional $1.6 billion for this program.[1]

5. Five-Year Modified Accelerated Cost Recovery System (MACRS) (IRS Code Section 168)

Certain biomass facilities are also eligible for the Modified Accelerated Cost-Recovery System (MACRS). Under the MACRS program, businesses may recover investments in certain properties through accelerated depreciation deductions. At the present time, combined heat and power facilities powered by biomass are in the five-year accelerated depreciation class for this program.

6. New Market Tax Credits

Although not specific to biomass projects, The New Markets Tax Credit (NMTC) Program could potentially provide an additional tax incentive for biomass facilities, depending on the location of the facility, and potentially, on the clients the facility serves. The purpose of the NMTC program is to encourage development that would benefit low income people and populations. It provides a tax credit against Federal income taxes for taxpayers making qualified equity investments in designated Community Development Entities (CDEs). The potential application of this tax credit program to any particular project is very site specific. A map of NMTC-qualifying areas in western Massachusetts can be found at http://www.ceimaine.org/content/view/215/233/. $13.4 billion in NMTC have been finalized or committed by May 2009 out of $19.5 billion awarded through 2008. An additional $1.5 billion was awarded in May 2009.

Federal Grants and Loans

The second major category of incentives is direct grants and loans from federal agencies including primarily the Department of Agriculture (USDA) and the Department of Energy (DOE). Some of the relevant programs from each agency are discussed below. The major portion of these funds are available through the Department of Energy, with the Exception of USDA's Biomass Crop Assistance Program (as discussed below). While there are several important programs at USDA that address smaller scale biomass energy options, these initiatives generally have low appropriations levels and, in many cases, have never been funded. By contrast the DOE programs generally focus on large scale production of liquid biofuels and/or electric generation and are funded at much higher levels than the array of USDA programs. Again, this creates incentives for certain biomass energy applications—biofuel production and electricity generation—at the federal level.

A. USDA Grant & Loan Programs

[1] http://www.taxalmanac.org/index.php/Sec._54._Credit_to_holders_of_clean_renewable_energy_bonds.

The majority of relevant USDA biomass programs are based on provisions of the 2008 Farm Bill. The relevant portions of the bill are focused on encouraging development of renewable biomass facilities. The Farm Bill specifically includes biomass in the definition of renewable energy, and defines "renewable biomass" broadly as "any organic matter that is available on a renewable or recurring basis from non-Federal land" and certain materials from public lands, if harvested during preventative treatments to reduce hazardous fuels, address infestation, or restore "ecosystem health." The following specific programs may provide incentives for biomass facilities and projects.

1. The Rural Energy for America Program (Sec. 9007 of 2008 Farm Bill)

The Rural Energy for America Program (REAP) provides financial assistance to rural communities in order for them to become more energy independent through increased production of renewable energy and energy efficiency. Grants and loan guarantees are available for energy efficiency and renewable energy investments (including biomass) for agricultural producers and rural small businesses. Grants may be up to 25% of project cost (up to a maximum of $500,000 for renewable energy projects), loan guarantees are capped at $25 million/loan and grants and loan guarantees together may be up to 75%. A portion of grants are reserved for small projects.

2. The Rural Energy Self-Sufficiency Initiative (Sec. 9009 of 2008 Farm Bill)

Authorizes a new program to provide financial assistance to increase energy self-sufficiency of rural communities. Provides grants to conduct energy assessments, formulate plans to reduce energy use from conventional sources, and install integrated renewable energy systems. Integrated renewable energy systems are defined as community-wide systems that reduce conventional energy use and incorporate renewable energy use. Federal-cost share for any grant is limited to 50% of project cost. The 2008 bill authorizes appropriations of $5 million annually for FY 2009-12.

3. Biomass Crop Assistance Program (BCAP) (Sec. 9011)

Created in the 2008 Farm Bill, BCAP is an innovative program intended to support establishment and production of eligible crops for conversion to bioenergy, and to assist agricultural and forest landowners with collection, harvest, storage, and transportation (CHST) of these eligible materials to approved biomass conversion facilities (BCF).

The program pays for up to 75% of establishment costs of new energy crops. In addition, farmers participating in a selected BCAP project area surrounding a qualifying BCF can collect 5 years of payments (15 years for woody biomass) for the establishment of new energy crops. An additional matching payment of up to $45/ton (on a $1 to $1 basis) to assist with collection, harvest, storage and transportation (CHST) of an eligible material to a BCF will also be available for a period of 2 years.

However, the launch of this new program has proved problematic. Rather than focusing funding on the front-end of the program, establishment of new energy crops, the Farm Service Agency (FSA) announced funds for the back-end of the program (via a Notice of Funding Availability (NOFA) for the Collection, Harvest, Storage and Transportation (CHST). It also interpreted CHST as an "entitlement" and allowed payment for a broad range of agricultural and forested materials delivered to an approved BCF.

The result amounted to a substantial, new subsidy for the existing wood market with significant market impact. Large numbers of existing biomass conversion facilities (led by lumber, pellet and paper mills currently burning wood for their own energy use without a federal subsidy) submitted applications to USDA to be approved as qualifying facilities. Consequently, funds obligated (though not yet spent) for BCAP through the end of March 2010 soared to over $500 million, more than seven times BCAP's estimated budget of $70 million in the 2008 Farm Bill. The USDA now estimates BCAP costs at $2.1 billion on CHST from 2010 through 2013.

The proposed rule for BCAP was announced February 8 with a final rule anticipated late summer 2010.

4. Forest Biomass for Energy (Sec. 9012)

Authorizes new competitive research and development program to encourage use of forest biomass for energy. To be administered by USDA's Forest Service; priority project areas include:

- developing technology and techniques to use low-value forest biomass for energy production
- developing processes to integrate energy production from forest biomass into biorefineries
- developing new transportation fuels from forest biomass
- improving growth and yield of trees intended for renewable energy

Authorizes appropriation of $15 million annually for FY 2009-12.

5. Community Wood Energy Program (Sec. 9013)

The Community Wood Energy Program is administered by the USDA and provides grants of up to $50,000 to state and local governments to develop community wood energy plans. Once a plan has been approved, qualified applicants may request up to 50% matching grants toward the capital costs of installing biomass energy systems. The Farm Bill authorizes $5 million per year from FY 2009 through FY 2012 for this program, but to date, no funds have actually been appropriated.

6. Business and Industry Guaranteed Loan Program

The Business and Industry Guaranteed Loan Program administered by USDA Rural Development. The purpose of the B&I Guaranteed Loan Program is to improve, develop, or finance business, industry, and employment and improve the economic and environmental climate in rural communities. A borrower may be a cooperative, corporation, partnership, or other legal entity organized and operated on a profit or nonprofit basis; an Indian tribe on a Federal or State reservation or other federally recognized tribal group; a public body; or an individual. A borrower may be eligible if they are engaged in a business that will reduce reliance on nonrenewable energy resources by encouraging the development and construction of renewable energy systems.

7. Rural Business Enterprise Grants (RBEGs)

The RBEG program provides grants for rural projects that finance and facilitate development of small and emerging rural businesses (defined as those that will employ 50 or fewer new employees and have less than $1 million in projected gross revenues). The program is not specific to biomass projects, but biomass projects could benefit from the grants.

B. Department of Energy Grant & Loan Programs

1. Renewable Energy Production Incentive

The Renewable Energy Production Incentive (REPI) provides financial incentive payments for electricity generated and sold by new qualifying renewable energy generation facilities. Qualifying facilities- including biomass facilities—are eligible for annual incentive payments for the first 10-year period of their operation, subject to the availability of annual appropriations in each Federal fiscal year of operation. This program serves as an alternative to the PTC for entities that are not eligible to take advantage of that tax program (i.e. entities that do not have federal tax liabilities).

2. DOE Loan Guarantee Program

Title XVII of the Energy Policy Act of 2005 authorizes DOE to provide loan guarantees for energy projects that reduce air pollutant and greenhouse gas emissions. DOE recently released its second round of solicitations for $10 billion in loan guarantees for energy efficiency, renewable energy, and advanced transmission and distribution projects under EPACT 2005 with a primary focus on transportation and electric generation. The final regulation provides that the DOE may issue guarantees for up to 100 percent of the amount of a loan. The 2009 ARRA extended the authority of the DOE to issue loan guarantees and appropriated $6 billion for this program. Under this legislation, the DOE may enter into guarantees until September 30, 2011.

3. Energy Efficiency and Conservation Block Grants

The Energy Efficiency and Conservation Block Grant (EECBG) Program provides federal grants to local government, Indian tribes, states, and U.S. territories to improve energy efficiency and reduce energy use and fossil fuel emissions in their communities. Activities eligible for funding include energy distribution technologies that significantly increase energy efficiency, including distributed generation, CHP, and district heating and cooling systems. A total of $3.2 billion was appropriated for the EECBG Program for fiscal year 2009. This funding will generally flow directly to states or local municipalities and is typically awarded on a competitive basis.

4. Sec. 471, Energy Independence and Security Act of 2007

Sec. 471 of the 2007 Energy Bill authorizes a program for Energy Efficiency and Sustainability Grants for implementing or improving district energy systems, combined heat and power applications, production of energy from renewable resources, developing sources of thermal energy and other applications. These funds would leverage investments by eligible public sector entities including institutions of high education, local governments, municipal utilities and public school districts. The Act authorizes $250 million for grants and $500 million for loans under this program for FY2009-2013 with maximum grants limited to $500,000. The program has never been funded.

5. Other ARRA Programs and Funding Opportunities Specific to Combined Heat and Power Facilities.

In addition to these major programs, the 2009 ARRA authorized a number of small grant and loan programs through DOE, some of which apply to potential biomass facilities including CHP and thermal district energy facilities. Of these, two grant opportunities were particularly relevant to biomass energy applications.

DOE-FOA-0000044, issued through the National Energy Technology Laboratory, provided $156 million for deployment of CHP systems, district energy systems, waste energy recovery systems, and efficient industrial equipment. Approximately 350 responses were submitted representing $9.2 billion in proposed projects with a $3.4 billion federal share, a demand far in excess of the available funding. DE-FOA-0000122, provided $21 million for community renewable energy development, with awards going to 5 projects nationwide.

The Department of Energy also has other solicitations specifically for combined heat and power systems. For example, the Industrial Technologies Program (ITP), part of DOE's Office of Energy Efficiency and Renewable Energy, recently released a funding opportunity for or up to $40 million in research, development and demonstration of combined heat and power (CHP) systems, based on annual appropriations, not ARRA funds.

II. Review and summary of Massachusetts state policies relevant to biomass energy and sustainable forestry.

Massachusetts has implemented policies to increase the use of biomass to meet energy needs in the electricity sector, the transportation sector, and the building heating sector, although state policies are focused primarily on implementing biomass to replace fossil fuels in the electricity and transportation sectors. Combined with the state's regulatory scheme designed to implement the Regional Greenhouse Gas Initiative (RGGI) (which sets an emissions cap on fossil fuel fired electrical generation systems of 25 megawatts or greater), this has created significant incentives in the state driving biomass towards larger scale electric generation capacity vs. smaller scale or thermal applications. A recent exception to this trend is the Massachusetts Green Communities Act of 2008 which established new Renewable and Alternative Energy Portfolio Standards (RPS and APS) which allow eligible CHP units to receive credits for useful thermal energy. This program promotes the installation and effective operation of new CHP units for appropriate residential, commercial, industrial, and institutional applications. It does not, however, eliminate or counterbalance the overall focus on encouraging development of the biomass electric power sector.

Following is a summary of the range of statutory and regulatory provisions that directly address biomass in Massachusetts, with an emphasis on biomass policy within the electricity sector.

A. Biomass in Renewable Energy Policy

1. Electricity

Massachusetts has two regulatory schemes that directly impact the incentives for developing biomass-fueled electricity in the state. The first is the Massachusetts Renewable Portfolio Standard (RPS), which is administered by the Department of Energy Resources (DOER), and the second is the implementation of the state's membership in the Regional Greenhouse Gas Initiative (RGGI), which is administered by the Department of Environmental Protection (DEP). We discuss RGGI and the Massachusetts regulatory scheme implementing RGGI in Part III, in the context of regional biomass policy initiatives. In this section of the paper, we discuss the implications for biomass energy under the RPS program regulations as currently written, recognizing that DOER has suspended RPS review of all proposed biomass-fueled electricity generators pending completion of the Manomet study.

The Massachusetts RPS program currently mandates that all retail electricity suppliers must include minimum percentages of RPS Class I Renewable Generation, RPS Class II Renewable Generation, and RPS Class II Waste Energy in the retail electricity they sell to consumers. For 2010, the Class I requirement is 5 percent, the Class II Renewable requirement is 3.6 percent, and the Class II Waste requirement is 3.5 percent. The definition of "eligible biomass fuel" under the RPS program is:

> *Fuel sources including brush, stumps, lumber ends and trimmings, wood pallets, bark, wood chips, shavings, slash and other clean wood that are not mixed with other unsorted solid wastes; by-products or waste from animals or agricultural crops; food or vegetative material; energy crops; algae; organic refuse-derived fuel; anaerobic digester gas and other biogases that are derived from such resources; and neat Eligible Liquid Biofuel that is derived from such fuel sources.*

It is notable that this definition contains no "sustainability" requirement. The RGGI definition, by contrast, does contain such a requirement, though the criteria for sustainability in that definition are not fleshed out at this time. This definition also includes liquid biofuels, which are expressly excluded from the definition of "eligible biomass" for purposes of the Massachusetts RGGI program.

Biomass facilities may qualify as RPS Class I or Class II generation units as long as they are classified as "low-emission, advanced biomass Power Conversion Technologies using an Eligible Biomass Fuel." Both the Class I and Class II RPS regulations also allow generators that co-fire to qualify as RPS Renewable Generation as long as certain requirements are met. This provision in the RPS program is analogous to the biomass exemption from carbon dioxide emissions accounting in the RGGI program.

In 2008, the Massachusetts Green Communities Act established new Renewable and Alternative Energy Portfolio Standards (RPS and APS) allowing Combined Heat and Power facilities to be included as an eligible technology provided the thermal output of a CHP unity is used in Massachusetts. APS eligible CHP units receive credits for the useful thermal energy of a CHP unit delivered to Massachusetts end-uses, subject to the formula included in the regulations. The DOER rules issued for this program will, for the first time in the Commonwealth, promote the installation and effective operation of new CHP units for appropriate residential, commercial, industrial, and institutional applications.

There are two other regulatory programs, aside from the DOER process for RPS approval, which could address the sustainability and the carbon neutrality of biomass-fueled electricity generation. The first is the Energy Facilities Siting Board review process for generation facilities, and the second is the Massachusetts Environmental Policy Act (MEPA).

All electricity generation facilities proposed in Massachusetts must be approved by the Energy Facilities Siting Board within the Department of Public Utilities. The Board reviews the environmental impacts of generation facilities to ensure that the plans for the facility are consistent with current health and environmental protection policies and the commonwealth's energy policies; and that the plans minimize environmental impacts and related mitigation costs. The Board is also responsible for adopting performance standards for emissions from generating facilities. The Board also has the authority to preempt other state agency or local regulatory bodies that pose hurdles to electricity facility siting. In making such decisions, the board has already has a track record of taking issues of carbon neutrality and sustainable fuel supplies into account.

The other regulatory vehicle for screening the sustainability and carbon neutrality of biomass electric generation facilities is environmental impact review through MEPA. However, as MEPA review is only mandatory for any new electric facility with a capacity of 100 MW or more, it may not have a great deal of promise for effective implementation of regulatory goals for biomass because facilities are unlikely to meet this size threshold. Further, the process is "informal," and "MEPA and [its implementing regulations] do not give the Secretary the authority to make any formal determination regarding . . . consistency or compliance" with "any applicable Federal, municipal, or regional statutes and regulations."

2. Transportation and Heating

The focus of Massachusetts policy on biomass in the transportation and heating sectors seems to be on liquid biofuels. In 2006, the commonwealth instituted a policy requiring the use of a minimum percentage of biofuels in state vehicles and instituting a pilot study on the use of biofuels in heating systems in state buildings. Additionally, the commonwealth created the "Advanced Biofuels Task Force" in late 2007 to explore how Massachusetts could accelerate use of advanced biofuels.[2] The Task Force issued a report, which explores the environmental life cycle of biofuels, and contains recommendations heavily focused on the transportation sector, in the spring of 2008. (Advanced Biofuels Task Force, 2007)

Following the report's publication, the commonwealth passed the Clean Energy Biofuels Act, which exempts cellulosic biofuels from the state gasoline tax, requires transportation diesel and home heating oil to contain 2-5% of cellulosic biofuels from 2010-2013, and requires the commonwealth to develop a low-carbon fuel standard that will reduce transportation GHG emissions by 10%. DOER has been implementing the Biofuels Act through regulations related to the tax exemptions for cellulosic biofuels. The proposed regulation includes a definition of "Lifecycle Greenhouse Gas Emissions" and eligibility criteria for the tax exemption that include requirements for the reductions in lifecycle GHG emissions achieved by eligible biofuels compared to fossil fuels.

B. Biomass and Forestry

Massachusetts has a statutory framework as well as administrative regulations addressing forest harvesting. By statute, the Commonwealth recognizes that:

> *the public welfare requires the rehabilitation, maintenance, and protection of forest lands for the purpose of conserving water, preventing floods and soil erosion, improving the conditions for wildlife and recreation, protecting and improving air and water quality, and providing a continuing and increasing supply of forest products for public consumption, farm use, and for the woodusing industries of the commonwealth.*

Accordingly, it is the policy of the Commonwealth that:

> *all lands devoted to forest growth shall be kept in such condition as shall not jeopardize the public interests, and that the policy of the commonwealth shall further be one of cooperation with the landowners and other agencies interested in forestry practices for the proper and profitable management of all forest lands in the interest of the owner, the public and the users of forest products.*

The Massachusetts Department of Conservation and Recreation (DCR) is the regulatory agency charged with administering timber harvesting on public and private forest lands. DCR has jurisdiction over all commercial forest cutting that produces more than 25,000 board-feet or 50 cords on any parcel of land. Under the regulations, any landowner planning a cut within DCR's jurisdiction must complete a "forest cutting plan." Proposed cuts that include a clearcut exceeding 25 acres are subject to additional regulatory process mandated by the Massachusetts Environmental Policy Act.

In addition to administering the Forest Cutting Practices regulations DCR has joined with DOER to form the Sustainable Forest Bioenergy Initiative (SFBI). The goal of the SFBI is to "provide research and development on forest management and market infrastructure needs, and enable the state to provide the resources necessary to develop the biomass supply market." The Initiative has produced a number of technical reports regarding woody biomass energy, woody biomass supply in the state, forest harvesting systems for biomass production, economic impact analyses, and silvicultural and ecological considerations for forest harvesting.

Documents produced under the SFBI state that the "carbon dioxide produced by burning wood is roughly equal to the amount absorbed during the growth of the tree." Other documents estimate between 500,000 and 890,000 dry tons of biomass from public and private forests located in the state can be sustainably harvested per year, and that the demand for woody biomass from forestry is approximately 526,000 dry tons per year. The SFBI has carried out extensive state-specific work on biomass energy and forest sustainability issues relevant to this study.

C. Other Massachusetts Incentives Related to Renewable or Alternative Energy Development and Biomass

The following paragraphs comprise a set of tax incentives and other programs available in Massachusetts that may have an impact on biomass development in the Commonwealth.

1. Renewable Energy Trust Fund—Two separate public benefits funds to promote renewable energy and energy efficiency for all customer classes. The renewable energy fund, known as the Massachusetts Renewable Energy Trust (MRET), is supported by a surcharge on customers of all investor-owned electric utilities and competitive municipal utilities in Massachusetts. The Massachusetts Technology Collaborative (MTC), a quasi-public research and development entity, administers the MRET with oversight and planning assistance from the Massachusetts Department of Energy Resources (DOER) and an advisory board. The MRET may provide grants, contracts, loans, equity investments, energy production credits, bill credits and rebates to customers. The fund is authorized to support a broad range of renewable energy technologies including low-emission advanced biomass power conversion technologies using fuels such as wood, by-products or waste from agricultural crops, food or animals, energy crops,

[2] Advanced Biofuels Task Force. (2007). Retrieved 2010 from http://www.mass.gov/?pageID=eoeeaterminal&L=4&L0=Home&L1=Energy%2c+Utilities+%26+Clean+Technologies&L2=Alternative+Fuels&L3=Clean+Energy+Biofuels+in+Massachusetts&sid=Eoeea&b=terminalcontent&f=eea_biofuels_biofuels_report&csid=Eoeea

biogas, liquid biofuels; and combined heat and power (CHP) systems less than 60 kilowatts (kW).

2. Large Onsite Renewables Initiative (Massachusetts Renewable Energy Trust Fund)—Program funds support grid-tied renewable-energy projects (excluding PV) greater than 10 kilowatts (kW) in capacity that are located at commercial, industrial, institutional and public facilities that will consume more than 25% of the renewable energy generated by the project on-site. The applicant and project site must be a customer of a Massachusetts investor-owned electric distribution utility or a municipal utility that pays into the Renewable Energy Trust. Grant awards may be used to facilitate the installation of renewable-energy projects on existing buildings (retrofits) or in conjunction with new construction/ major renovation projects, including green buildings.

3. Business Expansion Initiative—The Massachusetts Technology Collaborative (MTC), as administrator of the state's Renewable Energy Trust Fund, offers loans to support renewable energy companies entering or expanding within the manufacturing stage of commercial development. Companies that currently, or plan to, manufacture renewable energy technology products in Massachusetts are generally eligible. Products may be new or existing, or a combination of the two.

4. Clean Energy Pre-Development Financing Initiative (Massachusetts Technology Collaborative)—Offers grants and loans to support the development of grid-connected renewable energy systems in New England. Eligible technologies or resources include wind energy; naturally flowing water and hydroelectric power; landfill gas; anaerobic digestion; and low-emission, advanced power-conversion technologies using "eligible biomass fuel." Biomass and wind energy projects must have a minimum capacity of three megawatts (MW), and hydroelectric, landfill gas and digester gas projects must have a minimum capacity of 250 kilowatts (kW). Projects must be designed to lead to the development of new renewable grid-connected generating capacity for the wholesale electricity market. Therefore, more than 50% of the renewable energy produced must be provided to the wholesale market.

5. Massachusetts Technology Collaborative (MTC) - Sustainable Energy Economic Development (SEED) Initiative—Provides financial assistance to support renewable-energy companies in the early stage of development. Applicants are companies that generally have a unique technology but have not yet demonstrated commercial viability to an extent sufficient to attract venture capital. Awards of up to $500,000 are available as a convertible loan on a competitive basis. Since 2004, the Massachusetts Renewable Energy Trust has invested over $4.9 million in Massachusetts-based renewable energy companies through the SEED Initiative.

6. Net Metering—The state's investor-owned utilities must offer net metering. Municipal utilities may do so voluntarily. (The aggregate capacity of net metering is limited to 1% of each utility's peak load.

7. The Biomass Energy Policy and Market Development Program (U.S. Department of Energy's State Energy Program)—The Biomass Energy Policy and Market Development Program promoted biomass with a comprehensive biomass energy policy initiative to improve the policy and market conditions and foster biomass economic development. The project informed the Renewable Portfolio Standard eligibility criteria for biomass projects and forestry management, assessed the regional woody biomass resource, and evaluated the potential for rural economic development. It increased the use of biofuels and biodiesel for building heating through outreach, formal collaboration with other state agencies to formalize comprehensive biomass energy policy and implementation plan, engaging with public and private sectors to inform policy discussions and understand and address issues, promote project activities within state agencies and private market to adopt bioenergy fuels, legal review and input, outreach policy and project development to industry, municipalities, concerned citizens, and renewable energy developers.

8. Alternative Energy and Energy Conservation Patent Exemption (Corporate)—Corporate excise tax deduction for (1) any income received from the sale or lease of a U.S. patent deemed beneficial for energy conservation or alternative energy development by the Massachusetts Department of Energy Resources, and (2) any income received from the sale or lease of personal property or materials manufactured in Massachusetts and subject to the approved patent.

9. Alternative Energy and Energy Conservation Patent Exemption (Personal)—Personal income tax deduction for any income received from a patent deemed beneficial for energy conservation or alternative energy development. The Massachusetts Commissioner of Energy Resources determines if a patent is eligible.

10. Biodiesel Blend Mandate (Massachusetts Session Law 206)—All diesel motor vehicle fuel and all other liquid fuel used to operate motor vehicle diesel engines must contain at least 2% renewable diesel fuel by July 1, 2010; 3% renewable diesel fuel by July 1, 2011; 4% renewable diesel fuel by July 1, 2012; and 5% renewable diesel fuel by July 1, 2013. For these purposes, eligible renewable diesel fuel includes diesel fuel that is derived predominantly from renewable biomass and yields at least a 50% reduction in lifecycle greenhouse gas (GHG) emissions relative to the average lifecycle GHG emissions for petroleum-based diesel fuel sold in 2005. The Massachusetts Department of Energy Resources must also study the feasibility, benefits, and costs of applying the percentage mandates on a statewide average basis rather than for every gallon of diesel motor fuel sold.

11. Biofuels Incentives Study (Massachusetts Session Law 206)—A special commission is established to study the feasibility and effectiveness of various forms of incentives to promote the development and use of advanced biofuels in Massachusetts, including, but not limited to, production credits, the production and harvesting of woody biomass, feedstock incentives and direct consumer credits for the use of advanced biofuels in various applications. The commission reported the results of its investigation and recommendations in March 2009.

12. Massachusetts - Green Power Purchasing Commitment—In April 2007, Massachusetts Governor Deval Patrick signed Executive Order 484, "Leading by Example: Clean Energy and Efficient Buildings." This order establishes energy targets and mandates for state government buildings and directed state government agencies to procure 15% of annual electricity consumption from renewable sources by 2012 and 30% by 2020. This mandate may be achieved through procurement of renewable energy supply, purchase of renewable energy certificates (RECs), and/or through the production of on-site renewable power. Only renewable sources that qualify for the Massachusetts renewable portfolio standard (RPS) are eligible.

13. Boston - Green Power Purchasing—In April 2007, Boston Mayor Thomas Menino issued an executive order that established a green power purchasing goal of 11% for the city government, and a goal of 15% by 2012. The executive order also requires all existing municipal properties to be evaluated for the feasibility of installing solar, wind, bio-energy, combined heat and power (CHP), and green roofs and set goals for greenhouse gas emissions reductions, recycling, green building, vehicle fuel efficiency, biofuels use, and the development of the Boston Energy Alliance, a non-profit corporation dedicated to implementing large-scale energy efficiency, renewable energy, and demand response projects citywide.

III. Review and summary of regional policy and regulatory initiatives impacting development of biomass energy.

A. Regional Greenhouse Gas Initiative

Massachusetts is a member of the Regional Greenhouse Gas Initiative (RGGI), a group of ten New England and Mid-Atlantic states that has agreed to cap greenhouse gas (GHG) emissions from the generation of electric power and to lower this cap over time. Under the RGGI agreement, each participating state has been assigned a certain number of carbon dioxide allowances, serving as that state's emissions cap. The individual states are responsible for assigning carbon allowances to the covered emissions sources within the state, and to adopt rules to implement the emissions accounting, trading, and monitoring necessary to achieve the initial cap and subsequent reductions of GHG emissions. Eight of the ten participating states, including Massachusetts, exempt biomass-fueled electricity generation from carbon dioxide emissions accounting such that any carbon dioxide emitted from biomass-fueled processes is not counted against that state's carbon cap. The RGGI emissions cap applies to fossil fuel-fired electricity generators with a capacity of 25 megawatts or greater.

As a consequence of this program, Renewable Energy Credits are issued in Massachusetts (and the other RGGI states) for biomass-fueled electric power generation, providing a significant incentive and market driver for large scale biomass-fueled electric power generation over other uses such as thermal, Combined Heat and Power, or smaller scale applications.

In addition to the complete exemption from the RGGI system for generators whose fuel composition is 95 percent or greater biomass, the RGGI Model Rule and all participating states except for Maine and Vermont provide partial exemptions for facilities that co-fire with smaller percentages of biomass. This partial exemption provides that any carbon dioxide emissions attributable to "eligible biomass" may be deducted from a facility's total carbon dioxide emissions when calculating whether the facility's emissions are within its carbon-allowance budget.

The Model Rule defines "eligible biomass" as follows:

> *Eligible biomass includes sustainably harvested woody and herbaceous fuel sources that are available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, unadulterated wood and wood residues, animal wastes, other clean organic wastes not mixed with other solid wastes, biogas, and other neat liquid biofuels derived from such fuel sources. Sustainably harvested will be determined by the [participating state's designated regulatory agency].*

In Massachusetts, the regulation defines "eligible biomass" identically except that it deletes the language "and other neat liquid biofuels." Additionally, the Massachusetts definition states, "Liquid biofuels do not qualify as eligible biomass." It is unclear why the Massachusetts regulators decided to eliminate liquid biofuels from the definition, especially since liquid biofuels are included in the "eligible biomass fuel" definition in Massachusetts' RPS program. As illustrated in Table 1, below, several other states similarly exclude liquid biofuels from their RGGI definitions of "eligible biomass." In Massachusetts, the Department of Environmental Protection is charged with defining the sustainable harvesting criteria for sustainable harvesting of biomass under RGGI.

Exhibit A-1: Summary of biomass provisions in the RGGI implementing regulations of the ten participating RGGI states.

State	Allows deduction for biomass-attributable emissions	Includes liquids as eligible biomass	Uses December 2008 Model Rule for biomass calculation	Uses January 2007 Model Rule for biomass calculation
Massachusetts	X			X
Connecticut	X		X	
Delaware	X	X	X	
Maine				
Maryland	X	Not found	X	
New Hampshire	X	X	X	
New Jersey	X	X	X	
New York	X		X	
Rhode Island	X		X	
Vermont				

B. Midwestern Greenhouse Gas Reduction Accord and Western Climate Initiative

While RGGI is the only fully developed and implemented regional cap and trade program for GHG emissions reductions in the United States, several Midwestern states and the Canadian province of Manitoba have joined together to achieve GHG emissions reductions through their own regional cap and trade system. The Midwestern agreement is called the Midwestern Greenhouse Gas Reduction Accord (Accord), and in June 2009, the Accord's Advisory Group issued a set of recommendations for emissions reductions targets and for designing a regional cap-and-trade system. The Advisory Group recommended that a broader set of sectors be included in the emissions reduction program than RGGI covers, such that the program would cover not only electricity generation, but also industrial sources, fuels serving residential, industrial, and commercial buildings, and transportation fuels. However, the recommendations include an exemption for carbon dioxide emissions "from the combustion of biomass or biofuels, or the proportion of carbon dioxide emission from the combustion of biomass or biofuels in a blended fuel," which essentially mirrors the RGGI exemption.

After the Advisory Group recommendations were published, the Accord issued a draft Model Rule in October 2009 The rule contains a definition of "eligible biomass" that is exactly identical to the RGGI Model Rule definition, including the liquid biofuels measure. Additionally, the Accord's Model Rule includes the same provision allowing a GHG source to deduct all biomass-attributable GHG emissions from its total GHG emissions when determining compliance with the source's GHG allowance budget. The Accord's Model Rule does not, however, contain any provision detailing how the biomass-attributable GHG emissions are to be calculated.

Similar to RGGI and the Midwestern Accord, several western states and Canadian provinces have joined in the Western Climate Initiative to enact similar GHG emissions reductions through a cap-and-trade system. The WCI, like the Accord, recommends that the program cover not just electricity, but also transportation, industrial and commercial fossil fuel combustion, industrial process emissions, and residential fuel use. Further, the WCI has issued draft program recommendations, which include a recommendation that "biomass determined by each WCI Partner jurisdiction to be carbon neutral" should not be included in the cap-and-trade program, except for reporting purposes. Further, the recommendations state that "[c]arbon dioxide emissions from the combustion of pure biofuels, or the proportion of carbon dioxide emissions from the combustion of biofuel in a blended fuel" would not be included in the program. The WCI recommendations also indicate that each participating jurisdiction "will assess whether and how to include upstream emissions from biofuel and fossil fuel production." These recommendations, unlike the RGGI Model Rule or the Accord's recommendations and Model Rule, exhibit more caution regarding the carbon neutrality of biomass fuel use.

IV. Review and summary of outstanding state policies impacting development of biomass energy, with a focus on renewable energy, forest sustainability and climate issues.

This section provides a summary of relevant policies in several states with notable approaches to biomass development, with a particular focus on renewable energy incentives, forest sustainability and climate change issues. Specifically, this section: characterizes the state-level approach to biomass usage in general; reviews the typical basket of state policies that address biomass; highlights some outstanding state policies with regard to biomass; and concludes with a listing of relevant state policies. It is based on a review of eleven states' policies regarding biomass: Arizona, California, Connecticut, Maryland, Minnesota, Missouri, Oregon, Pennsylvania, Vermont, Washington, and Wisconsin.

The thrust of state policies promoting biomass and/or biofuels is focused on electric generation and less so on transportation and thermal. All surveyed states have numerous policies, programs and/or incentives to promote electric generation from renewable sources of energy, including biomass. A few states have policies to support the use of biomass/biofuels for transportation (California, Minnesota, Oregon, Pennsylvania, Washington, and Wisconsin) and/or for thermal production (Arizona, Connecticut, Missouri, Oregon, Pennsylvania, Vermont, Washington, and Wisconsin).

Typically, states include biomass as one of a number of sources of renewable energy in a variety of policies and programs aimed at increasing electric generation from renewable energy. A common method to advance biomass electric generation policies is via renewable portfolio standards, which typically mandate that utilities provide a certain percentage of renewably generated electricity by a certain date. Other common state policies supportive of biomass electric generation are net metering programs; public benefits funds which, among other activities, distribute grants and/or loans for biomass research and/or development; other grant and/or loan programs for biomass research and/or development; power purchasing programs at the state and/or local level; and a variety of tax incentives. The range of tax incentives includes: production tax incentives such as energy production tax credits, or deductions or exemptions for installing certain types of biomass manufacturing systems; sales tax incentives for purchasing qualifying equipment for harvesting, transportation, and manufacturing or processing of biomass; personal tax incentives such as income tax credits and deductions for installation of certain types of renewable energy systems; and property tax incentives such as exemptions, exclusions and credits for property (including equipment) used for the siting of qualifying manufacturing facilities or the transport of biomass.

States with large sources of biomass supply, such as Minnesota, Missouri, Oregon, Washington and Wisconsin, also tend to have biomass-specific policies or programs in addition to general programs such as renewable portfolio standards. These states are also likely to have biomass working groups or a biomass program (Connecticut, Minnesota, Oregon, Pennsylvania, and Vermont). Some have produced biomass reports, including woody biomass supply assessments. (Arizona, California, Minnesota, Oregon, Vermont, Washington, and Wisconsin). These reports typically focus more on biomass promotion and less on sustainability, and some discuss the linkage between biomass utilization and climate change. Finally, some states have produced woody biomass harvesting guidelines that focus on best management practices for harvesting woody biomass in an ecologically sensitive and sustainable manner (Minnesota, Missouri, Pennsylvania, and Wisconsin). All such harvesting guidelines are voluntary, guidance only.

The following state programs stand out regarding the sustainable utilization of biomass for renewable energy generation:

The Vermont Energy Act of 2009 aims to expand the market for renewable-energy technologies in Vermont in a number of innovative programs that address the issue from different directions. Its key elements include: clarification that the Clean Energy Development Fund's grants and loans also apply to thermal energy projects (discussed further below); a standard offer for renewable energy (discussed further below); incentives that allow utilities to recover permitting costs for renewable energy; pilot downtown-community renewable-energy projects in two towns, Montpelier and Randolph (Village Green Program); improvements to residential- and commercial-building standards; provision for the creation of clean energy assessment districts so that towns, cities, and incorporated villages can use municipal bonds to finance residential renewable-energy or energy-efficiency projects; and limitations on the power of municipalities and deeds to prohibit residential installation of renewable-energy and energy-efficiency devices, such as solar panels, residential wind turbines, and clothes lines.

The Vermont Clean Energy Development Fund, Vermont's principle renewable energy incentive program, has provided millions of dollars to wind, solar, biomass, and other renewable energy projects in the form of grants and loans over the past several years. The Vermont Energy Act of 2009 clarified the scope of the CEDF to include thermal energy and geothermal resources, including combined heat-and-power systems, which sets Vermont's program apart from most state programs. Grant funding is available to four categories of projects: pre-project financial assistance, small-scale systems (microturbines, fuel cells, and CHP), large-scale systems, and special demonstration projects. Proposed projects must have an electric generation component and be grid-connected; off-grid projects and thermal projects (except CHP systems) are not eligible. There is a special funding opportunity in 2009 for municipalities, public schools, and colleges to explore renewable energy projects and feasibility up to $5,000. Low-interest fixed-rate loans are available to individuals, companies, nonprofits and municipalities for purchasing land and buildings for qualifying projects, purchasing and installing machinery and equipment, and providing working capital. Eligible clean electric-energy technologies include solar, wind, biomass, fuel cells and combined heat and power.

The **Vermont Standard Offer for Qualifying SPEED Resources** was enacted as part of the 2009 Vermont Energy Act. It requires all Vermont retail electricity providers to purchase electricity generated by eligible renewable energy facilities through the Sustainably Priced Energy Enterprise Development (SPEED) Program. This "feed-in tariff" is intended to provide a reasonable return on investment to renewable energy facility developers, thereby spurring deployment of renewable energy. The program establishes a set price that utilities must pay to purchase renewable energy from certain qualifying sources, by means of long-term contracts. The standard offer price will be available to facilities with a plant capacity of 2.2 MW or less, for a total of 50 MW of renewable power state-wide. The applications for 50 MW of SPEED standard-offer contracts are fully subscribed and a lottery was implemented to select final solar and biomass projects. Wood biomass is included as a potential qualifying renewable energy source, but may only receive the standard offer if the plant's system efficiency is 50% or greater. If the program's goals (included in the appendix) are not met, then the RPS will become mandatory and require the state's electric utilities to meet any increase in statewide retail electricity sales between 2005 and 2012 by using renewables with associated attributes, by purchasing RECs, or by making an alternative compliance payment to the Vermont Clean Energy Development Fund.

Oregon is a biomass leader. It has developed a comprehensive wood biomass supply assessment at state and regional levels. The state's active **Forest Biomass Working Group** has produced a comprehensive analysis of forest biomass opportunities map that includes existing wood-based energy facilities and the power transmission grid. The **Oregon Strategy for Greenhouse Gas Reduction** aims to reduce wildfire risk by creating a market for woody biomass from forests. It incorporates use of biomass into discussions linking climate change, wildfire protection plans, and economic development for rural communities. It notes that an additional 100 MW produced from woody biomass plants would result in the thinning of 2.4 million acres over 30 years, and the average annual sequestration from reduced crown fires and improved forest health would be 3.2 million metric tons of CO2. This CO2 reduction is in addition to, and does not include, displacing fossil fuels with biomass fuels. It promotes biofuels use and production, and expands research on how climate change could affect expanded production of renewable power including bioenergy. **Oregon House Bill 2200** authorized the State Forester to establish programs to market, register, transfer or sell forestry carbon offsets on behalf of state forestland beneficiaries, the Forest Resource Trust, and other non-federal forest landowners. The bill recognizes a wide range of forest management activities—those designed to protect our environment as well as those designed to provide our wood products—as having the potential to give rise to forestry carbon offsets. Oregon's **Biomass Logging Bill** (SB 1072) promotes the use of biomass from logging projects on federal land as both a restoration tool and electricity generation mechanism. It also directs the Oregon Department of Forestry to participate in federal forest project planning and land management. It spells out that the "Policy of the State" of Oregon is to support efforts to build and place in service biomass fueled electrical power generation plants that utilize biomass collected from forests or derived from other sources such as agriculture or municipal waste. It requires the Oregon Board of Forestry to direct the State Forester to enter into stewardship contract agreements with federal agencies to carry out forest management activities on federal lands. Finally, the **Oregon Renewable Energy Action Plan** (REAP) outlines a plan of action for renewables. Specifically for biomass, it provides that twenty-five megawatts of new biomass-fueled electric generation will be built or under construction, in addition to 5 megawatts of biogas facilities; it allows biomass facilities to qualify for net metering and allows the Oregon Public Utility Commission to adopt rules to increase the 25-kilowatt limit on a net metering facility for customers of Portland General Electric and Pacific Power; it encourage the development and utilization of small energy efficient biomass heating and electrical systems for heating and providing power to institutions, state offices, schools, etc., especially in rural Oregon; and it promotes greater public awareness of the primary and secondary benefits of biomass energy production.

California's State Biofuels Development Plan / Biofuels Production Mandate and Alternative Fuel Use Study is notable for its ambition. California plans to use biomass resources from agriculture, forestry, and urban wastes to provide transportation fuels and electricity to satisfy California's fuel and energy needs. The state will produce its own biofuels at a minimum of 20% by 2010, 40% by 2020, and 75% by 2050. Regarding the use of biomass for electricity, the state shall meet a 20 percent target within the established state goals for renewable generation for 2010 and 2020. The Bioenergy Action Plan includes: research and development of commercially viable biofuels production and advanced biomass conversion technologies; evaluation of the greenhouse gas reductions benefits of bio-fuels and biomass production and use; evaluation of the potential for biofuels to provide a clean, renewable source for hydrogen fuel; and state agencies' purchase of flexible fuel vehicles as 50% of total new vehicles by 2010.

APPENDIX 2-A

18 SELECTED TECHNOLOGY PATHWAYS

Pathway #1: Power Plant—Electricity (green wood)

This technology pathway is fueled by green wood with bark. On average, woodchips have roughly 40 percent moisture content. This means that while one ton of dry woodchips would produce 16.5 million Btus[1] (MMBtu) of heat, one ton of green woodchips would produce only 9.9 MMBtu. The green wood with bark will have some implications on the emissions of this system as bark has high ash content. This technology pathway will use direct combustion using a fluidized bed. This combustion technique suspends the woodchips in midair using jets of upward-blowing air. This increases the contact between carbon and oxygen and hence increases efficiency. A medium (like sand, or lime) is used to make the process uniform and controllable. The resulting hot gases travel up from the furnace to the boiler to heat water and convert it into a high-pressure steam.

The high-pressure steam then travels to a condensing steam turbine, the secondary process in this pathway. When steam enters the turbine, it is hotter per unit weight than when it exits the turbine. Upon leaving, the exhaust steam is condensed below atmospheric pressure which increases the pressure drop between input and exhaust steam. This produces greater power per unit weight of the input steam. The spinning turbine creates electrical energy.

Lastly, when the hot gases travel out of the furnace, they are likely carrying some ash, fines, and other particulates. In order to reduce the particulate emissions from this pathway, an electrostatic precipitator (ESP) removes particles from the air using an electrostatic charge. Gases are not impeded as they move through the ESP, but particulates like dust and smoke remain instead of leaving with the gas. The clean flue gases are discharged to the atmosphere through a high stack.

Pathway #2: Power Plant—Electricity (co-fired, 20% green wood, 80% coal)

In this pathway, green wood with bark is most commonly co-fired with coal. In co-firing, biomass can burn simultaneously with coal, comprising 20 percent of the load that is combusted in a regular coal boiler system. No efficiency is lost in the process. The intent is to reduce the use of fossil fuel and substitute renewable biomass, which is low-carbon if sustainably managed, and sulfur oxide emissions are lowered because biomass has nearly no sulfur content. When the two fuels are burned and release hot gases, they heat water in the boiler which in turn heats the high-pressure steam needed for the condensing steam turbines (as described in Pathway #1). The turbines create electrical energy.

[1] Btu: British thermal unit, a standard unit of energy equal to the heat required to raise the temperature of one pound of water one degree Fahrenheit

In some current applications, co-firing has been found to increase PM emissions. In this pathway, an ESP will be an important component in collecting particulates from the flue gases.

Pathway #3: Power Plant—Electricity (coal)

This technology pathway utilizes bituminous coal, which is the most abundant type of coal in the United States. It is second highest in energy output (after anthracite). The coal is used in a direct combustion furnace. The hot gases created in the furnace travel upward to the boiler to heat water and convert that into a **steam**. The steam then moves into a condensing steam turbine, as used in Pathway #1. The spinning turbine creates electrical energy.

An ESP is used in this pathway to capture particulates.

Pathway #4: Power Plant—Electricity (natural gas)

This pathway utilizes natural gas. Natural gas is composed mostly of methane, has drastically more energy per unit than either oil or propane, and emits lower amounts of nitrogen oxides and carbon dioxide than oil or coal. In this pathway, it is combusted directly to create steam using simple cycle technology representative of most existing gas-fired systems. The steam moves to a gas turbine, also known as a combustion turbine. Three steps are involved in this process. First, incoming air gets compressed to a very high pressure. Then, the combustor burns the fuel, producing a high-pressure, high-velocity gas. As the gas moves through the combustion chamber, it spins the turbine that creates electricity.

No emissions control equipment is associated with this technology pathway.

Pathway #5: Thermal Energy (cordwood)

Green wood with bark is used in this pathway in the form of cordwood. Firewood is commonly measured in units of cords which are a measure of volume, not weight. A standard cord of stacked wood is equal to the amount of wood in a four foot by four foot by eight foot stack (this is equivalent to 128 cubic feet). The energy content of cordwood can vary widely based on species and moisture content. It is very important to note that cords are also used as a volume measure of roundwood and this roundwood cord measure is different (a cord of roundwood is only 85 cubic feet, compared to 128 cubic feet of cordwood). This difference between the two measures is due to less air space between pieces of cordwood that are cut, split, and neatly stacked.

The cordwood is loading by hand and combusted directly in a traditional boiler, such as may be found in a home's basement or possibly even an outdoor boiler. This boiler heats water which is used for domestic water and heating purposes (thermal energy) in a residential setting.

Pathway #6: Thermal Energy (cordwood)

This pathway also utilizes cordwood but is combusted in an EPA-certified boiler in a residential setting. These boilers combine high efficiency combustion with hydronic thermal storage. The hot water storage aids in increasing the system's efficiency because the boiler does not have to operate during times of low-load as long as enough thermal storage is available to meet the demand.

Pathway #7a: Wood Pellets (green wood)

This technology pathway produces pellets and is fueled by green wood with bark. The wood is processed so that it can go through the drying and densification process, in which the air is expelled from the wood at very high pressures and then formed into pellets. Natural plant lignin in the pellet material is melted during the extrusion process and holds the pellets together without glues or additives. Pellets have significantly lower moisture content than the woodchips from which they were created (six percent versus an average of 40 percent, respectively) which means they produce greater Btus per unit. This pathway, combined with 7b, represent the full energy implications of using pellets from forst, through production and combustion of pellets.

Pathway #7b: Thermal Energy (pellets)

After the densification of green wood with bark to create pellets, the process in this pathway is to use direct combustion to burn the pellets to create thermal energy. This combustion occurs in the furnace in which the pellets come in direct contact with the fire. The purpose of biomass burner technologies is to get all of the carbon in pellets to react with oxygen in the air to make carbon dioxide. As this is an exothermic reaction, it will generate a lot of heat. The challenge here is to convert all the carbon and get maximum heat. When the flue gas travels out of the furnace, water captures the heat and is then piped throughout the building or number of buildings for heating and domestic hot water. The water used for heating the air is then piped back to the furnace to be re-heated and looped out again.

The emission control device utilized in this pathway is a cyclone-baghouse combination. With the correct design and choice of fabric, particulate control efficiencies of over 99 percent can be achieved even for very small particles (one micrometer or less) by fabric filters or baghouses. The lowest emission rate for large wood-fired boilers controlled by fabric filters reported is 0.01 lb/MMBtu. For large thermal-only applications (boilers over four to five MMBtu), a baghouse is usually sufficient to handle particulate matter (PM) control (along with a multi-cyclone which is generally included with the boiler by the manufacturer). Considered with Pathway 7a, this represents an application using pellets at the commercial scale, from forest to combustion.

Pathway #8: Thermal Energy (green wood)

This technology pathway is fueled by green woodchips with bark and undergoes direct combustion in a fluidized bed (as described in Pathway #1). The interim product is hot water (and not high pressure steam). The water in the boiler will capture the heat from the combustion chamber and will then be piped through the building for heat and hot water, or thermal energy. The cold water will be piped back to boiler.

A fabric filter or baghouse will collect the particulates to lower the emission rates.

Pathway #9: Thermal Energy (heating oil)

This pathway involves the direct combustion of residual heating oil, which includes number 5 and 6 heating oils. These are often referred to as "heavy oils" because they are what remain after gasoline and distillate oils have been extracted in the distillation process. This oil is laden with high amounts of pollutants, sulfur dioxide being one of the greatest. Residual oil has a high viscosity so before it can be used in a boiler, it must be heated so that it flows more smoothly. Once this has been achieved, the oil gets combusted directly in a furnace where it heats water for thermal applications.

No emissions control equipment is associated with this technology pathway.

Pathway #10: Thermal Energy (natural gas)

This pathway involves the direct combustion of natural gas. The gas is combusted in a furnace where it heats water for thermal applications.

No emissions control equipment is associated with this technology pathway.

Pathway #11: CHP—Electricity (green wood)

In this pathway, the green wood with bark goes through direct combustion in a fluidized bed (as described in Pathway #1). In this pathway, the high-pressure steam moves through to the second part of the process that is in a backpressure steam turbine. The steam enters the turbine where it expands. During expansion, some of its thermal energy is converted into mechanical energy that runs an electrical generator. The low pressure steam that exits the turbine returns to the plant to satisfy thermal applications. As backpressure turbines satisfy both process and heating requirements, they are ideal for combined heat and power (CHP) applications that are far more efficient than electrical energy production alone.

An ESP will serve as the pollution control equipment to remove particulates from the air.

Pathway #12: Gasifier—Electricity (green wood)

In this pathway, the green wood with bark is used to create a producer gas using the process of gasification. Gasification is a thermo-chemical process that converts solid fuel materials into combustible gases that can then be used for heat and power. When biomass is heated with a fraction of what is needed for efficient combustion, it gasifies into the interim product, a mixture of carbon monoxide and hydrogen—synthesis gas or syngas or producer gas. Combustion occurs as a result of mixing oxygen with hydrocarbon fuel. Because gaseous fuels mix with oxygen more easily than liquid fuels, which in turn mix more easily than solid fuels, syngas inherently burns cleaner and more efficiently than the solid biomass from which it was made. One advantage of gasification technology is that it is a decentralized energy conversion system that operates economically even when used in small-scale applications. Although the technology is currently not commercially available in the United States, it has proven to be economical in many locations.

The producer gas is then used in an internal combustion engine to power a generator. The generator spins to create electrical energy while waste heat from both the gasifier and the internal combustion engine can be captured and used as thermal energy, thereby creating a CHP system.

Pathway #13: CHP—Electricity (heating oil)

Residual heating oil is combusted directly, in this pathway, to create steam. This pathway differs from the former because the steam moves through to a backpressure steam turbine. As backpressure turbines create both electrical and thermal energy, they are ideal for CHP applications that are far more efficient than electrical energy production alone.

No emissions control equipment is associated with this technology pathway.

Pathway #14: CHP—Electricity (natural gas)

In this technology pathway, natural gas is combusted directly to create steam. The steam travels to a backpressure steam turbine as described in Pathway #11. The electricity produced by the spinning generator and the over-pressurized steam that satisfies thermal applications at the plant fulfills the CHP component.

No emissions control equipment is associated with this technology pathway.

Pathway #15: Cellulosic Ethanol (green wood)

In order to create ethanol, green wood with bark goes through a primary process of hydrolysis and fermentation (ERRE, 2009). This is a multiple step process. First, sulfuric acid is mixed with the woodchips at which point a hydrolysis reaction occurs. Here, the complex chains of sugars that make up the hemicellulose in the wood get broken and release simple sugars. Later in the process, what cellulose remains gets hydrolyzed into glucose. This glucose then goes through the fermentation process, in which microorganisms convert it to ethanol.

As a by-product of ethanol production, lignin can get combusted directly to produce the electricity required for the production process, or, since more electricity is generally created than is needed, selling the electricity may help the process economics.

An ESP can be applied to the furnace in which the lignin is burned to reduce PM emissions.

Pathway #16: Bio-oil & Bio-Char (green wood)

In this Pathway, green wood with bark undergoes a primary process of pyrolysis at a bio-refinery. Pyrolysis is the rapid chemical decomposition of wood in the absence of oxygen, and occurs spontaneously when the temperature is high enough. This process breaks the wood down into a gas, liquid (bio-oil), and a solid (Biochar). By rapidly decomposing the biomass at high temperatures, it will result in a greater amount of bio-oil whereas slow pyrolysis will produce Bio-Char. Bio-oil can be substituted for conventional liquid fuels, and while it contains roughly 54 percent the heating value of #6 fuel oil (Innovative Natural Resource Solutions, 2004), its benefit is that it is sourced from a renewable resource rather than a non-renewable fossil fuel.

As bio-oil can be substituted for conventional fuels, it can be burned in a furnace to heat water for thermal energy applications.

This pathway utilizes an ESP as its emissions control equipment.

Pathway #17: Bio-products (green wood)

This pathway also utilizes green wood with bark to create a syngas through the process of gasification. Syngas is composed of hydrogen and carbon monoxide. The Fischer–Tropsch process (or Fischer–Tropsch Synthesis) is a set of chemical reactions that convert a mixture of carbon monoxide and hydrogen into liquid hydrocarbons. The process, a key component of gas-to-liquids technology, produces a petroleum substitute, typically from biomass for use as synthetic lubrication and as synthetic liquid fuel, such as ethanol. Electricity is also created by combusting lignin, the by-product of ethanol production.

An ESP is used to remove the particulates from the air exiting the plant.

Pathway #18: Gasification—Cellulosic Ethanol (green wood)

In technology pathway #6, green wood with bark undergoes a primary process of fast pyrolysis at a bio-refinery. The bio-oil produced from fast pyrolysis can be used to produce a variety of bio-products, such as plastics, glues, organic fertilizers, and fuel additives.

This pathway utilizes an ESP as its emissions control equipment.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2										TECHNOLOGY PATHWAYS SUMMARY									
3	No.	Technology Pathway	Main Product	Co-products	Typical Capacity	Unit	Hours of operation per year	Output Heat Mmbtu/yr	Gross Effi c.	Net Effi c	Heat Input MMBtu/yr	Btu/lb	Tons (dry) per year	Fuel Requirements lbs (dry) /MMBtu output heat	CO2 Emissions lbs/MMBtu input heat	CO2 Emissions lbs/MMBtu output heat	C Emissions lbs/MMBtu input heat	C Emissions lbs/MMBtu output heat	Maximum Affordable Cost of Biomass with 40% MC ($/ton)
4								(F)*(H)*3.412			(I)/(J)		(L)/(M)	(N)/(I)		(P)*(L)/(I)	(P)/3.6667	(Q)/3.6667	
5	1	Power	Electricity		50	MW	7,200	1,228,320	25%	25%	4,913,280	8,500	289,016	470.59	215.69	862.75	58.82	235.29	$31
6		(green wood)																	
7	2	Power	Electricity		500	MW	7,200	12,283,200	32%	32%	7,677,000	8,500	451,588	73.53	215.69	134.80	58.82	36.76	$31
8		(coal &									30,708,000	10,506	1,461,451	237.96	205.30	513.25	55.99	139.98	
9		green wood-									38,385,000	10,105	1,913,039	311.49	207.38	648.05	56.56	176.74	
10		20% co-fi ring)																	
11	3	Power	Electricity		500	MW	7,200	12,283,200	32%	32%	38,385,000	10,506	1,826,813	297.45	205.30	641.56	55.99	174.97	
12		(coal)																	
13	4	Power	Electricity		500	MW	7,200	12,283,200	33%	33%	37,221,818	1,028	36,207,994	2.95	117.00	354.55	31.91	96.69	
14		(Natural Gas)										cubic ft	dtherms	dtherms					
15	5	Thermal	Thermal		0.1	MMBTH	1,800	180	60%	60%	300	8,500	18	196.08	215.69	359.48	58.82	98.04	$104
16		Energy	energy																
17		(cordwood)																	
18	6	Thermal	Thermal		0.1	MMBTH	1,800	180	68%	68%	265	8,500	16	173.01	215.69	317.19	58.82	86.50	$104
19		Energy	energy																
20		(cordwood)																	
21	7a	Wood	Wood pellets		10,000	TPY		159,800	85%	85%	188,000	8,500	11,059	138.41	215.69	253.75	58.82	69.20	$0
22		pellets																	
23	7b	Thermal	Thermal		5	MMBTH	1,800	9,000	80%	80%	11,250	8,500	662	147.06	215.69	269.61	58.82	73.53	$167
24		energy	energy																(40% MC)
25		(pellets)																	
26	8	Thermal	Thermal		50	MMBTH	1,800	90,000	75%	75%	120,000	8,500	7,059	156.86	215.69	287.58	58.82	78.43	$104
27		(green wood)	energy																
28	9	Thermal	Thermal		50	MMBTH	1,800	90,000	80%	80%	112,500	152,000	740,132	8.22	173.90	217.38	47.43	59.28	
29		(oil)	energy									/gallon	gallons	gallons					
30	10	Thermal	Thermal		50	MMBTH	1,800	90,000	85%	85%	105,882	1,028	102,998	1.14	117.00	137.65	31.91	37.54	
31		(natural gas)	energy									cubic ft	dtherms	dtherms					
32	11	CHP	Electricity		5	MW	7,200	368,496	75%	25%	491,328	8,500	28,902	156.86	215.69	287.58	58.82	78.43	$104
33		(green wood)		Thermal	245,664	MMBtu													
34				Electrical	122,832														
35	12	Gasifi er	Electricity		5	MW	7,200	317,669	75%	29%	423,559	8,500	24,915	156.86	215.69	287.58	58.82	78.43	$104
36		(green wood)		Thermal	194,837	MMBtu													
37				Electrical	122,832	MMBtu													
38	13	CHP (oil)	Electricity		5	MW	7,200	341,200	75%	27%	454,933	152,000	2,992,982	8.77	173.91	231.88	47.43	63.24	
39				Thermal	218,368	MMBtu						per gallon	gallons	gallons					
40				Electrical	122,832	MMBtu													
41	14	CHP (gas)	Electricity		5	MW	7,200	297,775	80%	33%	372,218	1,028	362,080	1.22	117.00	146.25	31.91	39.89	
42				Thermal	174,943	MMBtu						cubic ft	dtherms	dtherms					
43				Electrical	122,832	MMBtu													
44	15	Cellulosic	Cellulosic	Thermal	100	MMGPY		10,256,098	50%	41%	20,512,195	8,500	1,206,600	235.29	127.26	254.51	34.71	69.41	$70
45		Ethanol	ethanol	Energy	1,846,098	MMBtu													
46	16	Bio-oil	Bio-oil	Thermal	15	MMGPY		1,542,667	65%	45%	2,373,333	8,500	139,608	181.00	118.63	182.50	32.35	49.77	$90
47		& Bio-char		Energy	474,667	MMBtu													
48	17	Bio-		Thermal	15	MMGPY		1,542,667	65%	45%	2,373,333	8,500	139,608	181.00	118.63	182.50	32.35	49.77	$90
49		products		Energy	474,667	MMBtu													
50	18	Cellulosic		Thermal	100	MMGPY		10,256,098	50%	41%	20,512,195	8,500	1,206,600	235.29	127.26	254.51	34.71	69.41	$70
51		Ethanol		Energy	1,846,098	MMBtu													
52		(gasifi cation)																	

APPENDIX 2-B: TECHNOLOGY PATHWAYS SUMMARY

Technology Pathways Summary Table

Orange = Formulas

Yellow = Typical Values assumed by BERC

Green = Calculated Values

Blue = Values taken from References

References (identified by cell)

Published Data by Biomass Power Plant: J5, K5

NREL: J7, K7, J11, K11, J13, K13

Published data by vendors: J15, K15, J18, K18, J21, K21, J23, K23, J26, K26, J28, K28,J30, K30, J32, K32, J35, K35, J38, K38, J41, K41, J46, K46, J48, K48, J50, K50

EERE, DOE: J44, K44

Calculated based on conversion of all carbon to carbon dioxide: P5, P7, P15, P18, P21, P23, P26, P32, P35, P44, P46, P48, P50

EIA: P8, P11, P13, P28, P30, P38, P41

Conversion Factors and Assumptions

1) 1 MWH = 3.412 MMBtu
2) High Heating Value of cellulosic ethanol = 84,100 (DOE)
3) High Heating Value of Bio-oil = 71,200 (DOE)
4) High Heating Value of Wood pellets (dry basis) = 17 MMBtu/ton (BERC)
5) High Heating Value of Wood chips (dry basis) = 17 MMBtu/ton (BERC)
6) High Heating Value of Coal = 10,506 Btu/lb (DOE)
7) High Heating Value of Natural Gas = 1,028 Btu/cubic ft.(DOE)
8) High Heating Value of #6 oil = 152,000 Btu/gallon(DOE)
9) 1 lb. Carbon = 3.6667 lbs CO_2
10) From Cell K12: co-firing with 20% biomass

NREL: Life Cycle Assessment of Coal Fired Power Production by Pamela L Spath & others at http://www.nrel.gov/docs/fy99osti/25119.pdf

EERE, DOE: Theoretical Ethanol Yield Calculator http://www1.eere.energy.gov/biomass/ethanol_yield_calculator.html

EIA: U S Energy Information Administration Independent Statistics and Analysis Voluntary Reporting of Green House Gases program (Fuel & energy Source Codes & emission coefficients) www.eia.doe.gov/oiaf/1605/coefficients.html

APPENDIX 2-C
AFFORDABLE PRICE OF BIOMASS—CALCULATION ASSUMPTIONS

Power		
Sale price of electricity	12.5	cents/kWh
Cost of biomass	33%	
Cost of biomass	0.04125	$/kWh
	3.02242E-06	$/Btu
	3.02	$/MMBtu
HHV of woodchips(dry)	8500	Btu/lb
HHV of woodchips(dry)	17	MMBtu/ton
HHV of woodchips(40 % MC)	10.2	MMBtu/ton
Affordable price of woodchips (40% MC)	31	$/ton
Thermal energy		
Oil price	3	$/gallon
heating value of oil	138,000	Btu/gallon
effciency	80%	
useful energy	110,400	Btu/gallon
cost of energy	27.17	$/MMBtu
Affordable price of woodchips as % of cost of oil	50%	
Affordable price of woodchips	13.59	$/MMBtu
effciency of woodchip boiler	75%	
available heat per ton	7.65	MMBtu/ton
affordable price of woodchips (40% MC)	104	$/ton
wood pellets (6% MC)		
HHV of wood pellets (6% MC)	15.98	MMBtu/ton
effi ciency	80%	
Available heat per ton	12.784	MMBtu/ton
Affordable price of wood pellets (6% MC) as % of cost of oil	75%	
Affordable price of wood pellets (6% MC)	20	$/MMBtu
Affordable price of wood pellets (6% MC)	261	$/ton
Woodchips to wood pellets		
effi ciency	85%	
wood pellets price	261	$/ton
woodchips MC	40%	
Wood pellets MC	6%	
woodchips required per ton of wood pellets	1.575	ton/ton
Affordable price of woodchips as % of cost of wood pellets	60%	
Affordable price of woodchips	85	$/ton

APPENDIX 3-A

REVIEW OF PREVIOUS STUDIES OF MASSACHUSETTS BIOMASS AVAILABILITY

In the past few years, the Massachusetts Sustainable Forest Bioenergy Initiative has funded two studies that address forest biomass availability in Massachusetts: Silvicultural and Ecological Considerations of Forest Biomass Harvesting in Massachusetts (Kelty, D'Amato, and Barten, 2008) and Biomass Availability Analysis—Five Counties of Western Massachusetts (Innovative Natural Resource Solutions (INRS), 2007). Here we review the components of these studies that focus on forest biomass, considering both their methodologies and results.

The general approach to forest biomass fuel used in these two studies is quite similar: both studies estimate net forest growth over an operable land base and equate this volume to biomass availability; thus, they assess how much wood could be harvested on an ongoing basis so that inventories do not decline below current levels. However, there are several important differences in the methods and details of implementing this approach and comparing their results with each other is not straightforward.

As will be seen in the following discussion, the data provided by Kelty et al. (2008) are presented in a manner that is most directly comparable to our own analysis. Kelty et al. (2008) provides two estimates of forest biomass availability on private lands to cover the wide range of potential responses by private landowners. The average of these two estimates is 750,000 green tons per year. When compared with our analysis, this average is consistent with our estimate of biomass supply at high biomass stumpage prices (the High-Price Biomass scenario). Kelty et al. (2008) is focused on forest growth and does not consider harvesting costs, energy prices, or general operational issues. This suggests that the biomass availability estimates provided by Kelty et al. would be reasonable estimates of supply only if bioenergy plants pay substantially higher prices for wood than in current markets.

Our adjustment of the INRS (2007) estimate to a statewide total suggests that biomass availability in Massachusetts would be about 1.4 million green tons per year. However, given the assumptions in this study, it is not clear how to adjust these estimates for sawtimber volumes and the split between private and public lands. Based on our review of this analysis, it would seem that the appropriate range for only biomass fuel on private lands would be about half of this volume, which suggests about 700,000 green tons, similar to the average of Kelty et al. (2008).

Review of "Silvicultural and Ecological Considerations of Forest Biomass Harvesting in Massachusetts"

The portion of this report that is focused on statewide biomass availability states that the question is: "what is the total annual sustainable harvest from Massachusetts forests (that is, the total annual harvest that would not exceed the total annual [net] forest growth)?" The report states that the intention was to assess the biomass levels that "exist in Massachusetts forests" on land that is "likely to be involved in timber harvesting." The report also provides a detailed analysis of biomass availability at the stand level, however, this analysis appears to be independent of the statewide analysis and have no influence on those results.

The methodology consists of three basic steps: 1) calculate average per-acre growth rates for timber stands in Massachusetts, with private and public lands evaluated separately; 2) identify the acreage available for harvesting; 3) adjust this total volume growth to separate sawtimber from other standing wood. These steps are described in more detail below and some key data are shown in Exhibit 3A-1.

Growth rates were developed on the basis of 50-year projections using the Forest Vegetation Simulator for the Northeast. The mean value of this time period was used as a measure of the growth rate in the future.

Two scenarios were established for private land areas because of the difficulty in predicting harvest activity among private landowners: one included all lands in size classes greater than or equal to 10 acres, while the other included only land greater than or equal to 100 acres. These two groups of private forest land areas were then reduced by 7% due to operational constraints such as terrain and wetland areas. Private lands were further reduced by 30% to adjust for landowners that were assumed would not be willing to harvest their lands for timber production.

Public forest land areas were reduced for operational constraints only. The reduction was 7%, the same as for private lands.

Total annual volumes of sustainable wood harvest were then calculated by multiplying growth per-acre growth rates times the number of acres available in each case. These data were then adjusted downward by 36% to account for timber that would likely be removed for sawtimber and not available to bioenergy facilities.

Results are presented iºn Exhibit 3A-1. "Sustainable" biomass availability was estimated to be about 500,000 green tons per year from public lands. For private lands, annual volumes ranged from 400,000-to-1.1 million green tons. Thus, the combined statewide total for biomass availability was estimated to range from 900,000-to-1.6 million green tons per year.

Exhibit 3A-1: Calculations for Biomass Availability Based on Kelty et al. (2008)

	Public	Private	
		≥ 100 acres	≥ 10 acres
Growth (dry tons/acre)	0.94	0.89	0.89
Growth (green tons/acre)	1.71	1.62	1.62
Net Land Area (acres)	465	379	1,073
Total Volume Growth (gt/yr)	795	614	1,736
Biomass Fuel Only (gt/yr)	509	393	1,111

Note: Data for dry tons and land areas taken directly from Exhibit 3-10 in Kelty et al. (2008). Data for green tons have been calculated assuming 45% moisture content.

Review of "Biomass Availability Analysis—Five Counties of Western Massachusetts"

The INRS (2007) report is comprehensive in its coverage of a wide range of sources of woody biomass. It is focused on the five western "core" counties of Massachusetts (Middlesex and Norfolk counties also are included as buffer counties, but are not reported separately from the buffer region). As above, we focus only on the portion of this study that addresses forest biomass.

This study considers forest biomass *growth* and forest *residues* separately. Forest biomass growth is estimated using net growth and removals from FIA data along with an adjustment factor for the growth of tops and branches. Net growth less removals results in estimated annual growth of 1.9 million green tons for western Massachusetts This volume is then reduced by half: "because of landowner constraints, access issues, economic availability, nutrient concerns and the need to harvest less than growth to address landscape-level forest sustainability concerns, INRS suggest that half of this wood be considered actually 'available' to the marketplace" This leaves a total of 960,000 green tons per year of biomass availability. An additional 110,000 green tons of forest residue are estimated to be available in this region (based on TPO data), resulting in an annual total of 1.1 million green tons.

These estimates do not consider the share of wood that might be used for sawtimber. The INRS report indicates that their estimate likely overstates the availability of forest biomass for this reason and others: "In practical terms, it is highly unlikely that this volume of wood could be harvested in an economic or environmentally responsible manner to supply biomass fuel. Further, some of this wood is sawlogs or other high-value material, and as such would be sent to other markets."

We have attempted to put these estimates on a basis that is comparable to the Kelty et al. (2008) analysis by adjusting them to the state level (growth and forest residues are not considered separately because of the small residue share). There are several alternatives for increasing these data from the western region to the state total, but it is not obvious which method would be most appropriate. Relative measures of timberland area, timber inventory, and growth-drain ratios result in expansion factors ranging from 20% to 40%. Thus, the total for biomass availability would be increased to 1.3-to-1.5 million green tons per year.

These estimates are close to the high end of the range (1.6 million green tons) provided by the Kelty et al. (2008). However, it is unclear how to adjust these estimates for potential sawtimber volumes. Kelty et al. (2008) project total net growth and then subtract the sawtimber component, whereas the INRS report projects "net growth less removals" so the growth estimates already partially reflect an adjustment for sawtimber. In addition, for purposes of comparison, it would be useful to separate the INRS volumes by private and public ownerships; however, the analysis reduces net growth on all forest lands by 50% and there appear to be no explicit assumptions regarding the mix of wood available from the two ownerships.

APPENDIX 3-B

LOGGING RESIDUE DATA AND ESTIMATION

Although estimation of this supply would seem to be straightforward, problems with logging residue data make it difficult to estimate both the total volume of residues that are generated as well as the share that is recoverable. Some of these problems are general conceptual issues, while others are specific to the Northeast and/or Massachusetts. An important issue relates simply to the definition of logging residues. Logging residues are not defined by the parts of a tree, but by what is left behind in the forest after a site has been logged. In addition to the obvious candidates for unused material after felling, such as crowns and branches, trees that have been killed or damaged during a logging operation are considered to be part of logging residues.[1] Thus, this becomes a difficult empirical issue because harvesting is dynamic and logging residues will change and evolve with technology, timber demand, and relative costs and prices. Once utilized, the material no longer conforms to the definition of logging residues and this can be a source of confusion.

Another important problem with logging residue data is that the parameters used to derive these estimates are from mill and timber utilization studies that are dated. The primary source of logging residue data in most studies is the Timber Products Output (TPO) reports from the U.S. Forest Service. These reports contain data on both softwood and hardwood residues and are disaggregated to the county level.[2] In the Northeast, these studies were last conducted in 1985, and thus do not reflect current utilization standards, prices, costs, and technologies. In addition, the calculation of logging residues requires a combination of surveys, each with its own problems and sampling errors. These problems are likely to be more serious in small states (where interstate trade is important) because wood flows and sourcing patterns can change substantially over time.

As it turns out, the logging residue data reported by TPO for Massachusetts could not be used because the on-line program generates the data incorrectly.[3] In order to generate logging residues that are consistent with the TPO methodology, we have applied the timber utilization matrices underlying the TPO estimates to their estimates of roundwood harvests.

According to the production data from the TPO reports, industrial roundwood production in Massachusetts is comprised of essentially two "products," sawlogs and pulpwood. ("Other industrial products" is a third category and accounts for 1% of the industrial roundwood total).[4] The volume of logging residues generated per unit of roundwood production is shown in Exhibit 3A-1. Logging residues from softwood harvests are less than for hardwoods because of differences in tree geometry and differences in end-use markets and products. Logging residues for pulpwood are less than for sawlogs because of the ability to utilize a higher proportion of the main stem.

The TPO data for Massachusetts in 2006 indicate that sawlogs accounted for 87% of the industrial roundwood production, and that softwood accounted for 60% of the sawlog production. Applying the coefficients in Exhibit 3B-1 to these data suggest that logging residues totaled 4.27 million cubic feet in 2006, or 50% of roundwood production. This implies that approximately 128,000 green tons of logging residues were generated in 2006 (using a conversion of 30 green tons per thousand cubic feet).

Exhibit 3B-1: Logging Residue Generation in Massachusetts By Product and Species Group
(cubic feet of logging residues per cubic foot of roundwood)

	Softwood	Hardwood
Sawlogs	0.43	0.67
Pulpwood	0.36	0.56

Source: Personal communication with USFS.

Importantly, these data appropriately measure only unutilized residues—wood left behind after a logging operation—and thus would be the correct measure of the total volume of residues that could be available for biomass. However, as noted earlier, a closer look at these data suggests that a significant share of this material can be attributed to breakage or residual stand damage, and thus could not be transported to a landing during a harvesting operation. For this reason, it is often assumed that 50% of "logging residues" are recoverable. Using this assumption, 64,000 green tons of logging residues would have been available for biomass supply in 2006.

Concerns about the TPO data and with implementing those estimates in a manner that is consistent with our projection and harvesting methodology have led us to a second approach: estimation of logging residue generation by calculating the volume of tops and limbs associated with harvesting trees of varying diameter

1 According to Forest Resources of the United States, 2002 (Smith et al.), logging residues are defined as: "The unused portions of growing stock and non-growing stock trees cut or killed by logging and left in the woods." This includes material that is sound enough to chip (and excludes rotten wood), downed dead trees, and downed cull trees. Material that has been badly damaged during logging but is still standing should be included in logging residues; however, the definitions are confusing in this regard.

2 The reports are available on-line (www.fia.fs.fed.us/tools-data/other/) and can be accessed on the National Renewable Energy Laboratory website.

3 The on-line TPO program reports that 8.451 million cubic feet of industrial roundwood products were produced in Massachusetts in 2006. The same number is reported as the total for "Logging Residues" and also for "Mill Residues."

4 There is also a large volume of fuelwood production; in fact, the volume is substantially higher than industrial roundwood production. However, the TPO methodology assumes that residential fuelwood harvests do not contribute to logging residues.

classes. From a biomass perspective, this approach provides a more useful estimate of "logging residues" since this material has a much better chance of being delivered to a landing at a reasonable cost using whole-tree harvesting methods.[5]

Exhibit 3B-2 shows the average volume of tops and limbs as a share of the merchantable tree volume in the standing inventory of live trees in Massachusetts. These data suggest that for all species combined, reasonable estimates of "logging residues" generated would be about 22%, on average, for sawtimber harvests and 35% for pulpwood. Thus, using the same data on industrial roundwood production as above (from TPO for 2006), logging residues would have been about 2.0 million cubic feet, or 60,000 green tons. Given that this material could be moved to a landing more easily because it consists strictly of tops and limbs, the recovery rate of this material for biomass fuel use could be considerably higher than 50%.

Exhibit 3B-2: Volume of Tops and Limbs as a Share of Merchantable Tree Volume
Based on Massachusetts Inventory Data, 2008

DBH, inches	Share
5.0–6.9	38%
7.0–8.9	31%
9.0–10.9	27%
11.0–12.9	24%
13.0–14.9	22%
15.0–16.9	21%
17.0–18.9	19%
19.0–20.9	18%
21.0–22.9	18%
23.0–24.9	17%

Source: Based on USFS, FIA data. DBH is tree diameter measured at breast height (4.5 feet above ground level).

[5] One shortcoming of this approach is that it is not possible to estimate how much of this topwood and limbwood may already be being utilized due to differing utilization standards for products, or for harvests of firewood.

APPENDIX 3-C

FIREWOOD DATA

Fuelwood is by far the largest market for timber cut in Massachusetts, but fuelwood data are poor because the market is unregulated with large numbers of consumers and producers, and there is a large personal use sector where consumers cut their own wood. The FCPs show some data on fuelwood harvests, but these numbers are small and only pertain to volumes that are associated with larger-scale commercial-based harvesting. The large majority of fuelwood cut in Massachusetts is not registered in these plans.

The Timber Product Output reports provide one estimate of fuelwood production in Massachusetts; however, these data are derived from U.S. Census data rather than collected directly from U.S. Forest Service surveys (the source of other TPO data). TPO data indicate that fuelwood production in Massachusetts in 2006 was 41.3 million cubic feet (517,000 cords or 1.3 million green tons), which would suggest that it would have accounted for about 83% of the timber harvest in Massachusetts (see Exhibit 3C-1.) According to this report, virtually all of the fuelwood comes from non-growing stock sources, which includes cull trees (rough and rotten), dead trees, tops and stumps of growing stock trees, and non-forestland sources of trees such as yard trees.

Exhibit 3C-1: Fuelwood Production in Massachusetts, 2006
Million Cubic Feet

	Industrial	Fuelwood	Total	Fuelwood (cords)
Growing Stock	7.0	1.2	8.2	15
Non-Growing Stock	1.5	40.1	41.6	502
Total	8.5	41.3	49.8	517

Source: TPO Reports (USDA, FS).

Unlike the data on industrial roundwood products, the data on fuelwood have not been collected by the USFS since some time prior to 1980. Since then, the data have been collected by Energy Information Administration as part of their Residential Energy Consumption Survey. These data are surveyed at the Census division level and allocated to individual states on the basis of the total number of housing units. In the case of Massachusetts, this methodology clearly overstates fuelwood consumption since Massachusetts accounts for about half of the housing units in New England. For example, in 2007, New England consumption was estimated to be about 927,000 cords, and 439,000 cords were allocated to Massachusetts. Prior to the time when this methodology was adopted, Massachusetts share of New England fuelwood consumption was only 35% in 1975 (and jumped to 49% when housing units were used as the basis of the allocation).

An important question in assessing biomass supplies in Massachusetts is how the residential fuelwood sector might interface with an expanded harvest of forest biomass fuel. Fuelwood is typically harvested in relatively small volumes and on small areas, often by landowners cutting for their own use. We have assumed that forest biomass harvests are unlikely to be integrated with harvests of residential fuelwood due to: 1) the number of acres cut in a typical fuelwood harvest; 2) the volume of logging residue left behind on each acre; and 3) the type of equipment used in these logging operations.

APPENDIX 3-D

A CLOSER LOOK AT BIOMASS POTENTIAL IN SOUTHERN NEW HAMPSHIRE

The analysis of inventories, industry location, and landowner attitudes in this report suggests that the border counties in New Hampshire, Vermont, and New York hold the most potential for increasing supplies of forest biomass. The New Hampshire border zone is the largest of these areas and the one with perhaps the best data. Here we look more closely at recent historical harvests (New Hampshire Report of Cut, 2008) and prices trends (New Hampshire Timberland Owner's Association, Timber Crier) in New Hampshire to see if there are any patterns that suggest than an expansion of timber production looks likely.

Timber Harvest Trends

In New Hampshire, the sawlog harvest declined from 2000 to 2006, with most of the decrease occurring by 2003. This is somewhat surprising given the strength of the housing market during this period. Part of this decline was offset by an increase in pulpwood and fuelwood harvest. Whole-tree chip production was fairly stable over these seven years, averaging about 800,000 green tons per year, equivalent to about 25% of New Hampshire's roundwood harvest.[6]

The harvest in the three counties of southern New Hampshire has been fairly stable as a share of the total cut in the state, fluctuating in the range of 20%–23% during 2000–2006. Similar to overall state trends, sawlog production declined (from 400,000 green tons in 2000 to 300,000 green tons in 2006), while pulpwood rose and whole-tree chip production remained steady at about 230,000 green tons.

Several aspects of these trends have implications for our analysis: 1) in spite of rising timber inventories in New Hampshire, recent harvest levels have been declining; 2) the southern counties share of the harvest has been stable; 3) in the southern counties, whole-tree harvests have been stable as a share of the overall harvest.

Overall trends do not show New Hampshire as a state that is expanding its forest products industries and its harvest levels. In general, this is not a positive trend for a bioenergy industry that is thought to have it biggest advantage when its raw material comes from integrated harvests that depend on other commercial products. Also, the southern share of state harvests has been stable: if the share were rising, one might have some evidence that the region has some competitive advantage, possibly in the area of wood supply.7

[6] Similar to Massachusetts, harvesting of fuelwood does not need to be reported if the volume is considered to be small and for personal use. For New Hampshire, this maximum volume is set at 20 cords.

[7] When sawlog production declines, the production and availability of mill residues will also decline (assuming sawlogs are milled in the "home" market). This is another factor that has negative consequences for biomass fuel supply.

The Relationship of Timber Harvest to Inventory Levels

A key metric that is often used to measure tightness in the timber market is the ratio of timber harvest to timber inventory (FIA data). We have compiled these estimates for the three New Hampshire regions to see if they provide any additional information about harvest potential (see Exhibit 3D-1). The cut-to-inventory ratio statewide is 1.1% (as noted in the table, the harvest data do not include residential fuelwood and logging residues which would likely move this ratio closer to 1.5%). These ratios decline as one moves from north to south: the ratio is 1.3% for the northern counties, 1.1% for the central counties, and 0.9% for the southern counties. As might be expected, timber inventories are growing more slowly in the central and northern areas. In fact, harvesting in the north has outpaced growth and timber inventories on private lands have declined an average of 500,000 green tons per year according to FIA estimates. These higher rates of harvesting in the north are also reflected in stocking levels which we estimate to be only 50 green tons per acre on private lands in the north, compared to 66 tons/acre in the central region, and 75 tons/acre in the south.

These data seem to suggest that if there are opportunities for expansion in New Hampshire, they may lie in the south. However, one cannot draw this conclusion on the basis of cut/inventory ratios or stocking levels alone unless the land in the inventory is similar and managed the same way. For example, it is common to see high cut/inventory ratios for industrial land ownerships (there are forest industry lands in northern New Hampshire) and lower cut/inventory ratios on non-industrial private lands where timber production may not be the most important objective of landowners.

Exhibit 3D-1: Harvest Ratios in New Hampshire
000 Green Tons and Percent

	Harvest	Cut/Inv
New Hampshire	3,238	1.1%
North	1,731	1.3%
Central	809	1.1%
South	698	0.9%

Notes: Harvest data is the average for 2000–2006 and includes sawlogs, pulpwood, fuelwood, and whole-tree chips. "Cut/Inv" is the ratio of harvest to growing stock on private and public timberland. Harvest data exclude residential fuelwood and logging residues and thus understate timber removals.

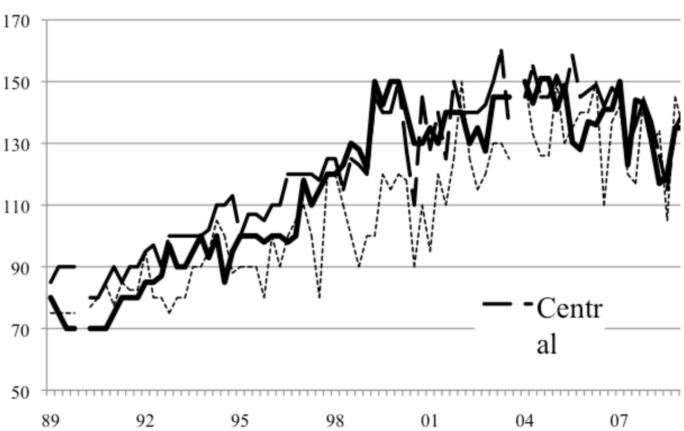
In spite of low cut/inventory ratios and expanding timber inventories in the southern counties of New Hampshire, the harvesting data have shown the south's position as a timber producer has been relatively stable. The southern counties are not growing in an absolute sense, nor have harvest levels increased relative to the central or northern areas. Importantly, we have also seen that whole-tree harvesting is already prevalent in southern New Hampshire. Thus, opportunities for expansion as part of integrated operations might be more limited than in other border zones where whole-tree harvesting is much less common.

Prices and Pockets of Opportunity

The final measure we consider—perhaps the single best indicator—is relative pricing. In a market in equilibrium, prices will track together. If prices deviate from the overall trend, particularly if they are drop lower at times, this may be due to weaker demand and might be an indicator that more timber can be harvested with the region remaining competitive. In Exhibit 3D-2, we have compared white pine sawtimber stumpage prices for the three regions of New Hampshire. We selected white pine because it accounts for about 50% of the sawtimber harvest and is widely distributed through the state (spruce/fir is the next largest species group with 13%, but it is almost entirely produced in the northern zone). We selected sawtimber because: 1) biomass is generally expected to be a follower of higher-valued commercial harvest; and, 2) biomass stumpage prices can easily diverge within regions because they are such a small share of total delivered costs.

Prices for white pine sawtimber stumpage in southern New Hampshire fall right in line with those in the central region suggesting that the buyers of wood can access both areas on an equal footing; hence the south would not appear ripe for greater expansion relative to other New Hampshire regions. The north is a bit more erratic, dropping below the southern price at times and for an extended period in 1997–2000. The data do not suggest any obvious gaps in the south that would be an incentive to build new capacity; in fact, the data suggest that such opportunities may have existed in the north during the 1990s. Although forests in the north have been cut more intensively than elsewhere in the state, prices have not moved higher suggesting that overall pressures on the resource remain similar in the three regions when ownership, attitudes, management objectives and other variables are taken into account.

Exhibit 3D-2: White Pine Sawtimber Stumpage Prices in New Hampshire
Dollars per 1,000 board feet International log rule



Source: New Hampshire Timberland Owner's Association, Timber Crier, various issues: mid-range stumpage prices.

REFERENCES

Innovative Natural Resource Solutions LLC. 2007. Biomass Availability Analysis—Five Counties of Western Massachusetts.

Kelty M.J., D'Amato A.W., and Barten P.K. 2008. Silvicultural and Ecological Considerations of Forest Biomass Harvesting in Massachusetts. Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA.

New Hampshire Report of Cut. 2008. Summary data generated by Matt Tansey, New Hampshire Division of Forest & Lands.

New Hampshire Timberland Owner's Association. Timber Crier. Various issues.

New Hampshire Timberland Owner's Association. 2010. Website: www.nhtoa.org.

Northeast State Foresters Association. 2007a. The Economic Importance and Wood Flows from the Forests of Maine, New Hampshire, Vermont and New York, 2007.

Northeast State Foresters Association. 2007b. The Economic Importance and Wood Flows from Vermont's Forests, 2007.

University of Massachusetts Amherst. 2008. Southern New England Stumpage Price Report. MassWoods, maintained by Paul Catanzaro. www.masswoods.net/sne_stumpage/

U.S. Department of Agriculture, Forest Service. Forest Inventory and Analysis National Program. Forest Inventory Data Online: www.fia.fs.fed.us/tools-data.

U.S. Department of Agriculture, Forest Service. Timber Product Output Mapmaker Version 1.0. On-line software for the Timber Product Output Database Retrieval System (TPO). www.fia.fs.fed.us/tools-data/other/

Vermont Department of Taxes. 2010. Annual Report. Division of Property Valuation and Review.

Vermont Forest Resource Harvest Summary. Various years. Vermont Department of Forests, Parks & Recreation.

APPENDIX 4–A
ECOLOGY OF DEAD WOOD IN THE NORTHEAST

Alexander M. Evans and Matthew J. Kelty

TABLE OF CONTENTS

1. INTRODUCTION

Although dead wood and decaying trees have historically had little commercial value, they do have substantial ecological value. This paper reviews the scientific literature to provide the background necessary to craft recommendations about the amount and type of dead wood that should be retained in the forest types of the northeastern U.S. Establishing the ecological requirements for dead wood and other previously low-value material is important because of the increased interest in this material for energy and fuel. More intensive extraction of biomass from the forest may impinge on the forest's ability to support wildlife, provide clean water, sequester carbon, and regenerate a diverse suite of plants.

This background paper covers the topics of dead wood, soil compaction, nutrient conservation, and wildlife habitat in temperate forests generally as well as in specific forest types of the Northeast. Complex issues related to carbon storage in forests and the climate impacts of using forest material for energy and fuel are very important and deserve an in-depth investigation beyond the scope of this paper. Similarly, this paper will not discuss the state of biomass harvesting in the U.S. (Evans 2008, Evans and Finkral 2009) or existing biomass harvesting guidelines (Evans and Perschel 2009) which have been addressed in other recent publications.

The goal of this background paper is to provide a concise summary that can inform discussions about biomass harvesting standards in the Northeast. However, it is important to note that this document makes no suggestions about how a biomass harvest should be conducted or what should be left in the forest after a harvest. Rather we have attempted to lay out the basic science on which recommendations can be built.

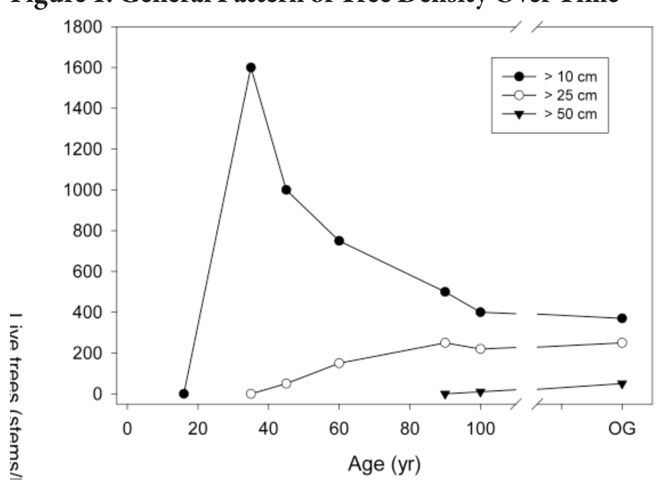
2. ECOLOGY OF DEAD WOOD IN THE NORTHEAST

2a. Dead Wood and Stand Development

Dead wood is important not only in terms of total volume or mass in a stand, but also in terms of piece size—usually measured as diameter at breast height (DBH) for snags (and for live trees) or diameter of the large end for down woody material (DWM). Large-diameter snags or down logs are important habitat for numerous animal species, persist for long periods, store nutrients, and provide substrate for seed germination.

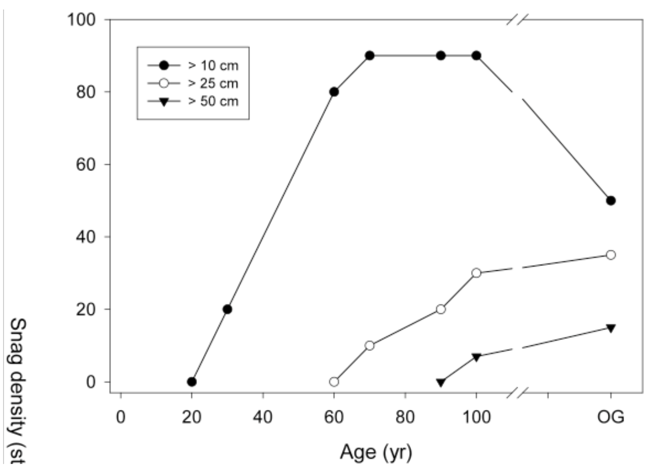
The process of dead wood accumulation in a forest stand consists of the shift from live tree to snag to DWM unless a disturbance has felled live trees, shifting them directly to DWM. The graphs below (Figures 1, 2, and 3) show the general pattern of the production of dead wood in total amount and size. The data in these graphs are taken from research in northern hardwood forests (Gore and Patterson 1986, Goodburn and Lorimer 1998, Hale et al. 1999, McGee et al. 1999, Nyland et al. 2000). The 4 in (10 cm) diameter size is within the range of the minimum size used in most coarse woody material (CWM) inventories. Fine woody material (FWM) refers to smaller-sized dead material. The graphs depict the patterns for a stand that had been harvested as a conventional clearcut, leaving a large amount of small woody material (nearly all <10 in (25 cm) diameter), but no trees >4 in (>10 cm) DBH and no snags. The pattern is shown from just after the clearcut (age 0)–age 100 years, and in the old-growth condition.

Figure 1. General Pattern of Tree Density Over Time



The young stand produces large numbers of trees (~600 stems/ac or ~1500 stems/ha) at age 30, and the intense competition among these trees causes mortality of smaller stems, which creates an increasing number of small snags (Figure 2). Trees begin to grow into 10 in (25 cm) DBH size by age 40, and trees of this size begin to dominate the stand by age 80. Snags of the 10 in (25 cm) DBH size begin to appear at age 60 as mortality of larger trees occur. Large live trees (>20 in or >50 cm) begin to appear at age 90—100, with snags of that size as well.

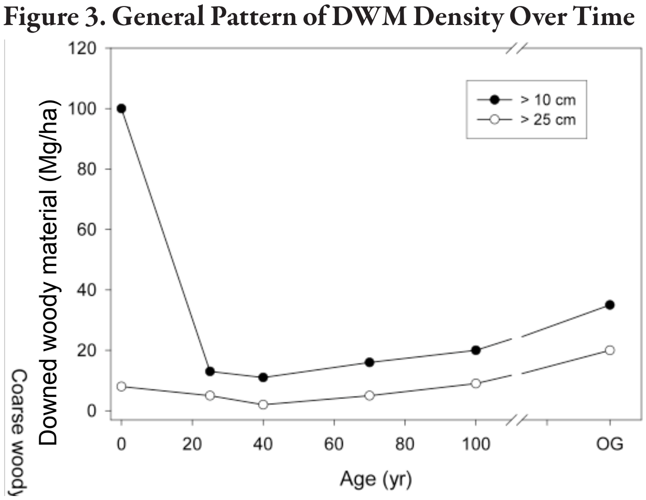
Figure 2. General Pattern of Snag Density Over Time



The large amount of DWM present just after the clearcut (which consists mostly of pieces <10 in (<25 cm) diameter) decomposes rapidly in the first 25 years and continues to decline in mass to age 40. From age 40—100 years, DWM increases as small snags fall, and then larger snags begin to contribute to DWM that include pieces >10 in (>25 cm) diameter. Very few large (> 20 in or >50 cm) pieces of DWM are produced. Large DWM often results from wind or other disturbances that fell large trees in the old-growth stage. Thus, large DWM tends to accumulate periodically from these disturbance pulses; whereas small DWM accumulates in a more predictable pattern in earlier stages of stand development.

This process produces the U-shaped pattern that is often described with a dearth of DWM in the intermediate ages (Figure 3). This pattern shows the importance of retaining large live trees and large snags at the time of harvest; they will contribute large DWM to the forest floor throughout the development of the stand.

Figure 3. General Pattern of DWM Density Over Time



2B. Wildlife and Biodiversity

Dead wood is a central element of wildlife habitat in forests (Freedman et al. 1996). Many forest floor vertebrates have benefited or depended on DWM (Butts and McComb 2000). In the southeastern U.S., more than 55 mammal species, over 20 bird species, and many reptiles and amphibian species were relying on dead wood (Lanham and Guynn 1996, Loeb 1996, Whiles and Grubaugh 1996) with similar numbers for the forests of the Pacific Northwest (Carey and Johnson 1995, McComb 2003). In New England, De Graaf and colleagues (1992) catalogued at least 40 species that rely on DWM.

Some examples of relationships between animals and DWM in the Northeast include a study showing that low densities of highly decayed logs (less than one highly decayed log/ha) had a negative impact on red-back voles (*Clethrionomys gapperi*) in a northern hardwood forest in New Brunswick, Canada (Bowman et al. 2000). DWM retention increased spotted salamander (*Ambystoma maculatum*) populations in a Maine study (Patrick et al. 2006). While DWM is important habitat for red-backed voles in Maine, it did not effect populations at volumes as low as 543 ft^3/ac (38 m^3/ha; McCay and Komoroski 2004). The quantity of DWM had no effect on white-footed mice (*Peromyscus leucopus*) abundance in an Appalachian study, but at the micro-site scale, mice were more often located near DWM (Marcus et al. 2002). Similarly, shrew (*Tupaia* sp.) showed minimal or no response to drastic decreases in the abundance of large logs in managed loblolly pine (*Pinus taeda*) forests of the southeastern coastal plain (McCay and Komoroski 2004) .

In aquatic environments, DWM provided crucial refuge from predation (Angermeier and Karr 1984, Everett and Ruiz 1993). Logs that fell in the water formed a critical component of aquatic habitat by ponding water, aerating streams, and storing sediments (Gurnell et al. 1995, Sass 2009). In fact, removal of large woody material from streams and rivers had an overwhelming and detrimental effect on salmonids (Mellina and Hinch 2009).

DWM is a key element in maintaining habitat for saproxylic insects (Grove 2002). For example, some specialist litter-dwelling fauna that depend on DWM appear to have been extirpated from some managed forests (Kappes et al. 2009). A study from Ontario suggests that overall insect abundance was not correlated with the volume of DWM, though abundance of the fungivorous insect guild was positively related to the volume of DWM (Vanderwel et al. 2006b). Extensive removal of DWM could reduce species richness of ground-active beetles at a local scale (Gunnarsson et al. 2004). More generally, a minimum of 286 ft^3/ac (20 m^3/ha) of DWM has been suggested to protect litter-dwelling fauna in Europe (Kappes et al. 2009).

Dead logs served as a seedbed for tree and plant species (McGee 2001, Weaver et al. 2009). Slash could be beneficial to seedling regeneration after harvest (Grisez, McInnis, and Roberts 1994). Fungi, mosses, and liverworts depended on dead wood for nutrients and moisture, and in turn, many trees were reliant on mutualistic relationships with ectomycorrhizal fungi (Hagan and Grove 1999, Åström et al. 2005). In general, small trees and branches hosted more species of fungus per volume unit than larger trees and logs; however larger dead logs may be necessary to ensure the survival of specialized fungus species such as heart-rot agents (Kruys and Jonsson 1999, Bate et al. 2004).

2C. SOIL PRODUCTIVITY

DWM plays an important physical role in forests and riparian systems. DWM added to the erosion protection by reducing overland flow (McIver and Starr 2001, Jia-bing et al. 2005). DWM also had substantial water-holding capacity (Fraver et al. 2002). DWM in riparian systems provided sites for vegetation colonization, forest island growth and coalescence, and forest floodplain development (Fetherston et al. 1995).

In many ecosystems, CWM decomposed much more slowly than foliage and FWM, making it a long-term source of nutrients (Harmon et al. 1986, Johnson and Curtis 2001, Greenberg 2002, Mahendrappa et al. 2006). DWM decomposed through physical breakdown and biological decomposition (Harmon et al. 1986). The diameter of each piece of DWM, temperature of the site, amount of precipitation, and tree species all influenced the rate of DWM decomposition (Zell et al. 2009). In general, conifers decayed more slowly than deciduous species (Zell et al. 2009). Other factors that encouraged decomposition included warmer temperatures, rainfall between 43 and 51 in/year (1100 and 1300 mm/year), and small-sized pieces (Zell et al. 2009). While there is great variation across ecosystems and individual pieces of DWM, log fragmentation generally appears to occur over 25–85 years in the U.S. (Harmon et al. 1986, Ganjegunte et al. 2004, Campbell and Laroque 2007).

In some ecosystems, DWM represents a large pool of nutrients and is an important contributor to soil organic material (Graham and Cromack Jr. 1982, Harvey et al. 1987). However, review of DWM in Northern coniferous forests suggested that DWM may play a small role in nutrient cycling in those forests (Laiho and Prescott 2004). The same review showed that DWM contributes less than 10 percent of the nutrients (Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), and Magnesium (Mg) returned in aboveground litter annually, and approximately five percent of the N and P released from decomposing litter or soil annually (Laiho and Prescott 2004). Although DWM is often low in N itself, N fixation in DWM was an important source of this limiting nutrient in both terrestrial and aquatic ecosystems (Harmon et al. 1986). There was a wide range of non-symbiotic N fixation, but temperate forests received average input of about 1.8–2.7 lb/ac/yr (2–3 kg/ha/year) of N (Roskoski 1980, Yowhan Son 2001).

A review of scientific data suggests that when both sensitive sites (including low-nutrient) and clearcutting with whole-tree removal are avoided, then nutrient capital can be protected (see also Hacker 2005). However, there is no scientific consensus on this point because of the range of treatments and experimental sites (Grigal 2000). It is important to emphasize that the impact on soil nutrients is site dependent. Low-nutrient sites are much more likely to be damaged by intensive biomass removal than sites with great nutrient capital or more rapid nutrient inputs. A report on impacts of biomass harvesting from Massachusetts suggested that with partial removals (i.e., a combination of crown thinning and low thinning that removes all small trees for biomass and generates from 9–25 dry t/ac or 20–56 Mg/ha) stocks of Ca, the nutrient of greatest concern, could be replenished in 71 years (Kelty et al. 2008). The Massachusetts study was based on previous research with similar results from Connecticut (Tritton et al. 1987, Hornbeck et al. 1990). Leaching, particularly of Ca due to acidic precipitation, can reduce the nutrients available to forests even without harvests (Pierce et al. 1993). However, the Ca-P mineral apatite may provide more sustainable supplies of Ca to forests growing in young soils formed in granitoid parent materials (Yanai et al. 2005).

15 years of data from Hubbard Brook Ecosystem Study indicate that a whole-tree clear cut did not result in the depletion of exchangeable Ca pools (Campbell et al. 2007). The Environmental Impact Statement from the White Mountain National Forest (2005 p. 3–19) demonstrated the variation in Ca removed by treatment and forest type, though even whole-tree clear cut was estimated to remove only four percent of the total Ca pool. A study of an aspen/mixed-hardwood forest showed that even with a clearcut system, Ca stocks would be replenished in 54 years (Boyle et al. 1973). Minnesota's biomass guidelines present data that showed soil nutrient capital was replenished in less than 50 years even under a whole-tree harvesting scenario (Grigal 2004, MFRC 2007). Whole-tree clearcutting (or whole-tree thinning, e.g., Nord-Larsen 2002) did not greatly reduced amounts of soil carbon or N in some studies (Hornbeck et al. 1986, Hendrickson 1988, Huntington and Ryan 1990, Lynch and Corbett 1991, Olsson et al. 1996, Johnson and Todd 1998). Lack of significant reduction in carbon and N may be due to soil mixing by harvesting equipment (Huntington and Ryan 1990). However, intensive cutting, such as clearcutting with whole-tree removal, can result in significant nutrient losses (Hendrickson 1988, Federer et al. 1989, Hornbeck et

al. 1990, Martin et al. 2000, Watmough and Dillon 2003)—in one case, 13 percent of Ca site capital (Tritton et al. 1987).

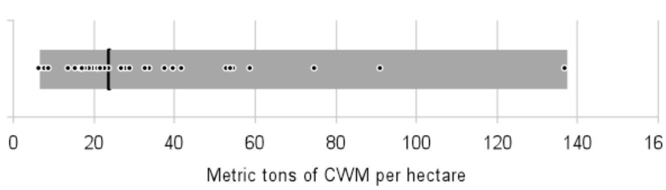
Low-impact logging techniques that reduce soil disturbance can help protect nutrient capital (Hallett and Hornbeck 2000). Harvesting during the winter after leaf fall can reduce nutrient loss from 10–20 percent (Boyle et al. 1973, Hallett and Hornbeck 2000). Alternatively, if logging occurs during spring or summer, leaving tree tops on site would aid in nutrient conservation. Nordic countries have demonstrated that leaving cut trees on the ground in the harvest area until their needles have dropped (one growing season) can also reduce nutrient loss (Nord-Larsen 2002, Richardson et al. 2002).

2D. QUANTITIES OF DEAD WOOD

Site productivity and the rate of decomposition helped determine the amount of dead wood in a given stand (Campbell and Laroque 2007, Brin et al. 2008). As mentioned above, DWM decomposition varies greatly but generally occurs over 25–85 years in the U.S. (Harmon et al. 1986, Ganjegunte et al. 2004, Campbell and Laroque 2007). All mortality agents including wind, ice, fire, drought, disease, insects, competition, and senescence create dead wood (Jia-bing et al. 2005). Of course, these mortality agents often act synergistically.

A review of 21 reports of quantitative measures of DWM in Eastern forest types shows great variability across forest types and stand development stages (Roskoski 1980, Gore and Patterson 1986, Mattson et al. 1987, McCarthy and Bailey 1994, Duvall and Grigal 1999, Idol et al. 2001, Currie and Nadelhoffer 2002). The reports ranged from 3–61 t/ac (7 to 137 Mg/ha) with a median of 11 t/ac (24 Mg/ha) and a mean of 15 t/ac (33 Mg/ha; see Figure 4). Measurements of old forests (>80 years old), had a median of 11 t/ac (24 Mg/ha) and a mean of 13 t/ac (29 Mg/ha) in DWM.

Figure 4. Distribution of DWM Measured in Eastern Forests



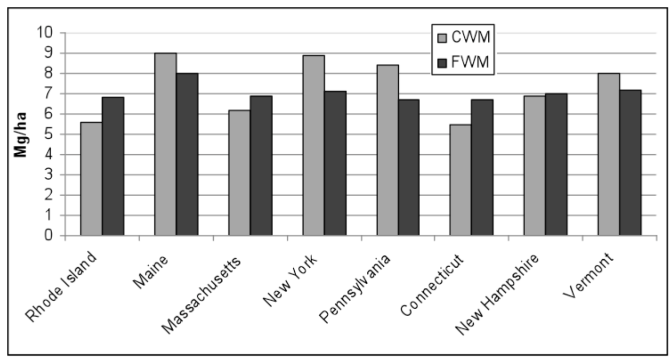
The gray bar shows the range of DWM measurement, the black line shows the median value, and each dot represents one measurement of DWM.

In contrast, a study of U.S. Forest Service inventory plots found a mean of 3.7 t/ac (8.3 Mg/ha) and a median of 2.9 t/ac (6.5 Mg/ha) of DWM across 229 plots in the Northeast (Chojnacky et al. 2004 see Figure 2). This low level of DWM across the landscape may be due to widespread clearcutting in the 1880-1930 period.

Figure 5. U.S. Forest Service Inventory Estimates of Deadwood Data from Chojnacky et al. 2004

3. Research by Forest Type

The following section uses the best available scientific literature to examine the dead wood dynamics of specific forest types in the Northeast. This region encompasses three ecological provinces including Northeastern mixed forest, Adirondack-New England mixed forest-coniferous forest, and Eastern broadleaf forest (McNab et al. 2007). Major forest types in the region are white/red/jack pine (*Pinus* sp.), spruce-fir (*Picea* sp. - *Abies* sp.),



oak-hickory (*Quercus* sp. - *Carya* sp.) or transitional hardwood forests, and northern hardwood forests (Eyre 1980).

The average year round temperature in the Northeast is 46°F (8°C). Winter temperatures average 24°F (-4.3°C) while summer temperatures average 67°F (19.6°C; National Climate Data Center 2008). The prevailing wind direction, from west-to-east, creates a continental climate except for coastal areas moderated by the Atlantic Ocean (Barrett 1980). On average, the region receives 41 in (104 cm) of precipitation which is evenly distributed throughout the year (National Climate Data Center 2008). Elevations range from sea level to mountain tops above 5,300 ft (1,600 m), but much of the region is set on upland plateaus between 500 ft and 1500 ft (150 and 460 m; Barrett 1980). Glaciation created young soils which vary considerably across small spatial scales (Barrett 1980).

Much of the southern portion of Northeastern forests was cleared for agriculture in the early 19th century, leaving less than one percent of the forest cover in an old-growth condition (Cogbill et al. 2002). Currently much of the region is comprised of second- or third-growth forest that has yet to reach late seral stages (Irland 1999). There are about 80 million ac (32 million ha) of timberlands (areas where commercial timber could be produced) and about 4 million ac (1.6 million ha) of reserved forest where harvests are not permitted (Alvarez 2007). Approximately 1,272 million ft3 (36 million m^3) of wood are harvested annually out of 3,157 million ft3 (89 million m^3) of net tree growth (Alvarez 2007).

3A. SPRUCE-FIR FORESTS

Spruce-fir forests dominate the inland areas of Maine as well as the mountain tops northernmost portions of New York, New Hampshire, and Vermont. These forests have cold temperatures and relatively coarse, acidic soils (Barrett 1980). Dead wood is important in spruce-fir ecosystems. For example, in Maine (the state with the greatest area of spruce-fir forests in the Northeast), DWM, snags, and cavity trees are important habitat for 20 percent of bird, 50 percent of mammal, 44 percent of amphibian, and 58 percent of reptile species found there (Flatebo et al. 1999). Animals that rely on DWM in spruce-fir forests include pine marten (Martes americana atrata) (Kyle and Strobeck 2003) and may include some saproxylic vertebrates (Majka and Pollock 2006).

In 2001, researchers found the volume of down dead wood in Maine's spruce-fir forest to be 530 ft^3/ac (37 m^3/ha) or 3.4 t/ac (7.5 Mg/ha) (Heath and Chojnacky 2001, Table 36). While the average was 3.4 t/ac (7.5 Mg/ha) non-industrial private lands only had 3 t/ac, public lands had 3.3 t/ac, while industrial lands had 3.7 t/ac (Heath and Chojnacky 2001, Table 37). The quadratic-mean, large-end diameter of down wood in Maine's spruce fir-forests measured 6.7 in (17 cm; Heath and Chojnacky 2001). The number of dead trees in nine red spruce-balsam fir forests ranged from 85–232/ ac (210–574/ ha) or from 11–43 percent of the basal area (Tritton and Siccama 1990). The nine paper birch-red spruce-balsam fir stands survey ranged from 33–86 dead trees/ac (81–212/ha) or 11–35 percent of basal area (Tritton and Siccama 1990), and overall, 14 percent of the trees in Maine were standing dead (Griffith and Alerich 1996). Dead wood provided an important substrate for spruce and hemlock seedling development (Weaver et al. 2009). While a commercial clearcut reduced the area of dead wood available for seedling growth, 5- and 20-year-selection cutting cycles were not statistically different from the uncut reference stand with 362–501 ft^2/ac (83–115 m^2/ha) of dead wood (Weaver et al. 2009).

As described above, spruce-fir forests tend to have two peaks in DWM over time: one early in stand development and a second peak after the stem exclusion phase (Figure 3). For example, one study showed a change from 63 t/ac (28 Mg/ha) in a stand <20 years, 22 t/ac (10 Mg/ha) in the 41–60-year age class, to 117 t/ac (52 Mg/ha) in the 61–80-year age class, and returning to less than 56 (25 Mg/ha) in the 101–120-year age class (Taylor et al. 2007). Fraver and colleagues (2002) showed that pre-harvest an Acadian forest had 10 t/ac (23 Mg/ha) of DWM. The harvest in this study increased the mass of DWM, but more of the pieces were small diameter (Fraver et al. 2002). While the harvest method (whole tree, tree length, or cut to length) and harvest system affect the amount of DWM left after harvest, many studies do not specify how material was removed.

Snag densities in balsam fir forests of Newfoundland followed a similar pattern over time. Stands contained nearly 16 snags/ac (40/ha) the first year post harvest; then the density declined below the 4 snags/ac (10/ha) required by the regional forest management guidelines at 20 years post harvest; and finally the number of snags returned to initial levels in the 80–100 years post-harvest stands (Smith et al. 2009). Smith and colleagues (2009) recommended retention and recruitment of white birch snags to ensure sufficient snag and DWM density. The Canadian province of Newfoundland and Labrador requires retention of 4 snags/acre while Maine recommends retention of 3 snags greater than 14 inches DBH and one greater than 24 inches DBH (Flatebo et al. 1999, Smith et al. 2009). Other guidelines recommend between 5 and 6 snags/acre greater than 8 inches and an additional 4–6 potential cavity trees (Woodley 2005).

A study of two old-growth balsam and black spruce sites demonstrated a wide range of average DWM piece sizes even in unmanaged lands. In the two study sites, the average diameter of the DWM structures were 54.8 cm and 16.1 cm; average height of snags was 4.73 m and 2.52 m; and length of logs were 5.91 m and 4.81 m (Campbell and Laroque 2007). The differences between the two sites are due, in part, to differences in rates of decomposition, i.e., higher rates of decomposition reduce the average size of DWM pieces.

One study of pre-commercial thinning in spruce-fir forests showed that the mass of DWM was reduced from 29–15 t/ac (64–34 Mg/ha; Briggs et al. 2000). In one study of a spruce-fir whole tree clearcut in Maine, 35 percent of organic matter was in trees and 12 percent was in woody litter and forest floor (Smith Jr et al. 1986). In that study, 23 t/ac (52 Mg/ha) of DWM were left after the harvest, but the whole-tree removal took about 91 percent of N, P, K, and Ca from the site, which was between 2 and 4 times the nutrient removal from a bole-only harvest (Smith Jr et al. 1986). Depletion of Ca is of some concern in Maine, though not as great a concern as in the Central and Southeastern U.S. (Huntington 2005). Spruce-fir forests generally incorporate Ca into merchantable wood at 1.6 kg Ca/ac/yr (1.6 kg ha-1yr-1; Huntington 2005).

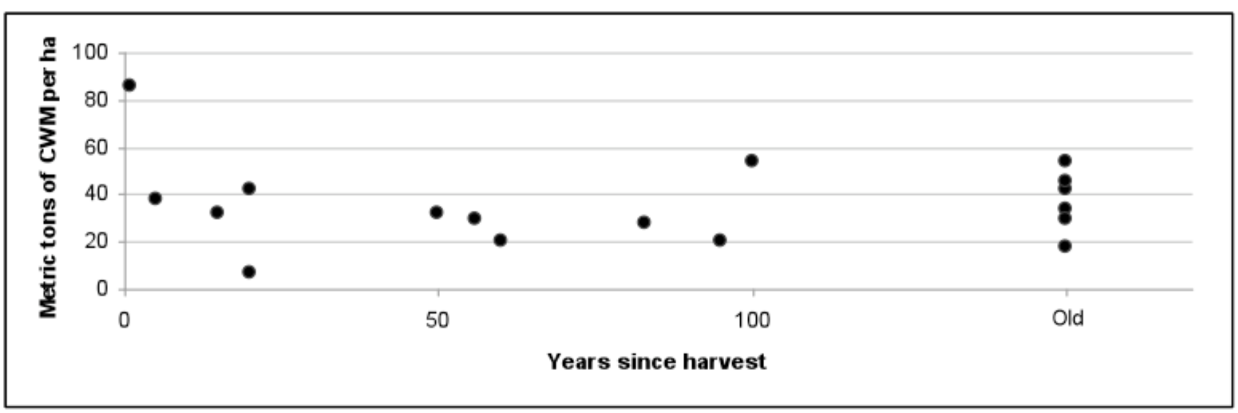
Some sites such as Weymouth Point, Maine, have documented Ca-depletion problems (Smith Jr et al. 1986, Hornbeck et al. 1990, Briggs et al. 2000). The rate of weathering replenishment of Ca in Maine is uncertain, and the Ca-rich mineral apatite may be an important source of Ca (Huntington 2005, Yanai et al. 2005). Climate change and the associated warming and species composition shift may exacerbate Ca depletion in spruce-fir forests (Huntington 2005).

3B. NORTHERN HARDWOOD FORESTS

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).

In general, the amount of DWM in northern hardwood forests follows the 'U' pattern mentioned above. Young stands have large quantities of DWM; mature stand have less; and older or uncut stands have more. For example, a study in New Hampshire measured 38 t/ac (86 Mg/ha) of DWM in a young stand, 14 t/ac (32 Mg/ha) in mature stands, 20 t/ac (54 Mg/ha) in old stand, and 19 t/ac (42 Mg/ha) in an uncut stand (Gore and Patterson 1986). Gore and Patterson (1986) also note that stands under a selection system had lower quantities of DWM, i.e., 16 t/ac (35 Mg/ha). A review of other studies identified similar temporal patterns and quantities of DWM (see Figure 6 from data described in Roskoski 1977, Tritton 1980, Gore and Patterson 1986, McCarthy and Bailey 1994, McGee et al. 1999, Bradford et al. 2009).

Figure 6. Quantities of DWM in Northern hardwood forests Forests



Data described in Gore and Patterson 1986, McCarthy and Bailey 1994, McGee et al. 1999, Bradford et al. 2009, and Roskoski 1977

Estimates of the volume of down dead wood in Maine's northern hardwood forests are 598 ft^3/ac (42 m^3/ha) or 9 t/ac (20.5 Mg/ha Heath and Chojnacky 2001). Keeton (2006) estimates a volume of 600 ft^3/ac (42 m^3/ha) of DWM in a multi-aged northern hardwood forest.

The number of dead trees in five hemlock-yellow birch forests range from 16–45/ac (40–112/ha) or from 3–14 percent of the basal area (Tritton and Siccama 1990). The 14 sugar maple-beech-yellow birch stands survey ranged from 14–99 dead trees/ac (35–245/ha) or 5–34 percent of basal area (Tritton and Siccama 1990). Other estimates of snag densities in northern hardwood forests include 5/ac (11/ha) (Kenefic and Nyland 2007), 15/ac (38/ha) (Goodburn and Lorimer 1998), and 17/ac (43/ha) (McGee et al. 1999). Tubbs and colleagues (1987) recommend leaving a between of one and ten live decaying trees/acre of least 18 inches DBH.

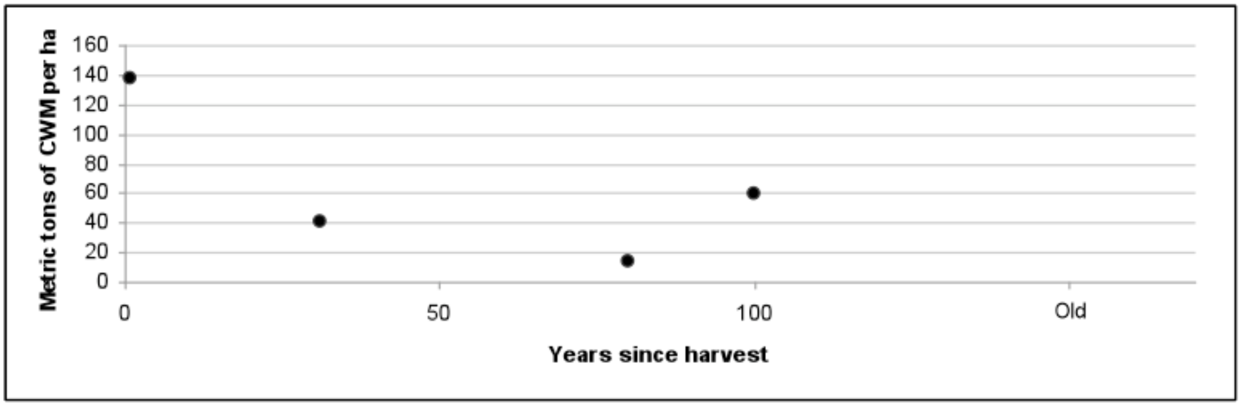
The number of cavity trees is another important habitat element in northern hardwood forests that is reduced by harvest. For example, studies in northern hardwood forests have shown a reduction from 25 cavity trees/ac (62/ha) before harvest and to 11 (27/ha) afterward (Kenefic and Nyland 2007). Another study measured 7 cavity trees/ac (18/ha) in old-growth, 4/ac (11/ha) in even-aged stand, and 5/ac (13/ha) in a stand selection system (Goodburn and Lorimer 1998).

3C. TRANSITION HARDWOOD FORESTS

Oak-hickory forests occupy the southernmost portions of the region. The oak-hickory forests are also considered a transitional forest type between the northern hardwood forests type and the Appalachian hardwoods that dominate further south (Westveld 1956).

As with the other forest types discussed, DWM density tends to follow a 'U' shape in oak-hickory forests. For example, Idol and colleagues (2001) found 61 t/ac (137 Mg/ha) in a one-year post-harvest stand, 18 t/ac (40 Mg/ha) in a 31-year-old stand, and 26 t/ac (59 Mg/ha) in a 100-year-old stand. Tritton and colleagues (1987) measured 5.8 t/ac (13 Mg/ha) in an 80-year-old stand in Connecticut.

Figure 7. DWM in Oak-Hickory Forests



Data described in (Tritton et al. 1987, Idol et al. 2001)

Estimates of the volume of down dead wood in Maine's oak-hickory forests are 244 ft^3/ac (17 m^3/ha) or 0.7 (1.5 Mg/ha; Heath and Chojnacky 2001). Wilson and McComb (2005) estimated the volume of downed logs in a western Massachusetts forest at 143 ft^3/ac (10 m^3/ha).

Out of seven oak stands in Connecticut, the number of dead trees ranged from 19–44/ac (46–109/ha) or 5–15 percent of basal area (Tritton and Siccama 1990). The decadal fall rates of snags in a Massachusetts study varied from 52–82 percent (Wilson and McComb 2005). Snags, particularly large-diameter snags, provide important nesting and foraging sites for birds (Brawn et al. 1982). In general, wildlife habitat requirements for dead wood are poorly documented, but it is clear that some wildlife species rely on dead wood in oak-hickory forests (Kluyver 1961, DeGraaf et al. 1992).

A study in Appalachian oak-hickory forests showed that the decomposing residues left after a sawlog harvest increased concentration of Ca, K, and Mg in foliage and soils after 15 years in comparison to a whole-tree harvest (Johnson and Todd 1998). However, the study found no impacts on soil carbon, vegetation biomass, species composition, vegetation N or P concentration, soil-bulk density, or soil N because of the whole-tree harvest (Johnson and Todd 1998).

3D. White Pine and Red Pine Forests

Pine forests are found in the coastal areas of Maine and New Hampshire and much of central Massachusetts. Pine forests tend to occupy sites with coarse-textured, well-drained soils (Barrett 1980).

Estimates of the volume of down dead wood in Maine's pine forests are 255 ft^3/ac (18 m^3/ha) or 1.6 t/ac (3.5 Mg/ha; Heath and Chojnacky 2001). A review of research on DWM in the red pine forests of the Great Lakes area showed that there were 50 t/ac (113 Mg/ha) of DWM in an unmanaged forest at stand initiation and 4.5 t/ac (10 Mg/ha) in a 90-year-old stand (Duvall and Grigal 1999). In comparison, the managed stand Duvall and Grigal (1999) studied had less DWM at both initiation 8.9 t/ac (20 Mg/ha) and at 90 years 2.9 t/ac (6.6 Mg/ha). The same review showed the unmanaged stand had 30 snags/ac (74/ha) while the managed forest had 6.9/ac (17/ha; Duvall and Grigal 1999). Red and white pine that fall to the ground at time of death will become substantially decayed (decay class IV of V) within 60 years (Vanderwel et al. 2006a).

While not a recognized forest type, stands with a mix of oak, other hardwoods, white pine, and hemlock are common. Many of the red oak and white pine stands on sandy outwash sites are susceptible to nutrient losses because of a combination of low-nutrient capital and past nutrient depletion (Hallett and Hornbeck 2000).

4. REFERENCES

Alvarez, M. 2007. The State of America's Forests. Society of American Foresters, Bethesda, MD.

Angermeier, P. l., and J. r. Karr. 1984. Relationships between Woody Debris and Fish Habitat in a Small Warmwater Stream. *Transactions of the American Fisheries Society* 113(6):716-726.

Åström, M., M. Dynesius, K. Hylander, and C. Nilsson. 2005. Effects of Slash Harvest on Bryophytes and Vascular Plants in Southern Boreal Forest Clear-Cuts. *Journal of Applied Ecology* 42(6):1194-1202.

Barrett, J. W. 1980. The Northeastern Region. Pages 25-65 in J. W. Barrett, editor. *Regional Silviculture of the United States*. John Wiley and Sons, New York, NY.

Bate, L. J., T. R. Torgersen, M. J. Wisdom, and E. O. Garton. 2004. Performance of Sampling Methods to Estimate Log Characteristics for Wildlife. *Forest Ecology and Management* 199(1):83-102.

Bowman, J. C., D. Sleep, G. J. Forbes, and M. Edwards. 2000. The Association of Small Mammals with Coarse Woody Debris at Log and Stand Scales. *Forest Ecology and Management* 129(1-3):119-124.

Boyle, J. R., J. J. Phillips, and A. R. Ek. 1973. "Whole Tree" Harvesting: Nutrient Budget Evaluation. Journal of Forestry 71(12):760-762.

Bradford, J., P. Weishampel, M.-L. Smith, R. Kolka, R. A. Birdsey, S. V. Ollinger, and M. G. Ryan. 2009. Detrital Carbon Pools in Temperate Forests: Magnitude and Potential for Landscape-Scale Assessment. *Canadian Journal of Forest Research* 39(4): 802–813.

Brawn, J. D., W. H. Elder, and K. E. Evans. 1982. Winter Foraging by Cavity Nesting Birds in an Oak-Hickory Forest. *Wildlife Society Bulletin* 10(3):271-275.

Briggs, R. D., J. W. Hornbeck, C. T. Smith, R. C. Lemin, and M. L. McCormack. 2000. Long-Term Effects of Forest Management on Nutrient Cycling in Spruce-Fir Forests. *Forest Ecology and Management* 138(1-3):285-299.

Brin, A., C. Meredieu, D. Piou, H. Brustel, and H. Jactel. 2008. Changes in Quantitative Patterns of Dead Wood in Maritime Pine Plantations over Time. *Forest Ecology and Management* 256(5):913-921.

Butts, S. R., and W. C. McComb. 2000. Associations of Forest-Floor Vertebrates with Coarse Woody Debris in Managed Forests of Western Oregon. *The Journal of Wildlife Management* 64(1):95-104.

Campbell, J. L., C. T. Driscoll, C. Eagar, G. E. Likens, T. G. Siccama, C. E. Johnson, T. J. Fahey, S. P. Hamburg, R. T. Holmes, A. S. Bailey, and D. C. Buso. 2007. Long-Term Trends from Ecosystem Research at the Hubbard Brook Experimental Forest. GTR-NRS-17, U.S. Forest Service, Northern Research Station, Newtown Square, PA.

Campbell, L. J., and C. P. Laroque. 2007. Decay Progression and Classification in Two Old-Growth Forests in Atlantic Canada. Forest Ecology and Management 238(1-3):293-301.

Carey, A. B., and M. L. Johnson. 1995. Small Mammals in Managed, Naturally Young, and Old-Growth Forests. *Ecological Applications* 5(2):336-352.

Chojnacky, D. C., R. A. Mickler, L. S. Heath, and C. W. Woodall. 2004. Estimates of Down Woody Materials in Eastern Us Forests. *Environmental Management* 33:S44-S55.

Cogbill, C. V., J. Burk, and G. Motzkin. 2002. The Forests of Presettlement New England, USA: Spatial and Compositional Patterns Based on Town Proprietor Surveys. *Journal of Biogeography* 29(10-11):1279-1304.

Currie, W. S., and K. J. Nadelhoffer. 2002. The Imprint of Land-Use History: Patterns of Carbon and Nitrogen in Downed Woody Debris at the Harvard Forest. *Ecosystems* 5(5):446-460.

DeGraaf, R. M., M. Yamasaki, W. B. Leak, and J. W. Lanier. 1992. New England Wildlife: Management Forested Habitats. General Technical Report NE-144, USDA Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Duvall, M. D., and D. F. Grigal. 1999. Effects of Timber Harvesting on Coarse Woody Debris in Red Pine Forests across the Great Lakes States, USA. 12(29):1926-1934.

Evans, A. M. 2008. Synthesis of Knowledge from Woody Biomass Removal Case Studies. The Forest Guild, Santa Fe, NM.

Evans, A. M., and A. J. Finkral. 2009. From Renewable Energy to Fire Risk Reduction: A Synthesis of Biomass Harvesting and Utilization Case Studies in Us Forests. *Global Change Biology Bioenergy* 1(3):211-219.

Evans, A. M., and R. T. Perschel. 2009. An Assessment of Biomass Harvesting Guidelines. The Forest Guild, Santa Fe, NM.

Everett, R. A., and G. M. Ruiz. 1993. Coarse Woody Debris as a Refuge from Predation in Aquatic Communities. *Oecologia* 93(4):475-486.

Eyre, F. H. 1980. *Forest Cover Types of the United States and Canada*. Society of American Foresters, Bethesda, MD.

Federer, C. A., J. W. Hornbeck, L. M. Tritton, C. W. Martin, R. S. Pierce, and C. T. Smith. 1989. Long-Term Depletion of Calcium and Other Nutrients in Eastern Us Forests. *Environmental Management* 13(5):593-601.

Fetherston, K. L., R. J. Naiman, and R. E. Bilby. 1995. Large Woody Debris, Physical Process, and Riparian Forest Development in Montane River Networks of the Pacific Northwest. *Geomorphology* 13(1-4):133-144.

Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. Biodiversity in the Forests of Maine: Guidelines for Land Management. University of Maine, Cooperative Extension, Orono, ME.

Fraver, S., R. G. Wagner, and M. Day. 2002. Dynamics of Coarse Woody Debris Following Gap Harvesting in the Acadian Forest of Central Maine, U.S.A. *Canadian Journal of Forest Research* 32(12):2094-2105.

Freedman, B., V. Zelazny, D. Beaudette, T. Fleming, G. Johnson, S. Flemming, J. S. Gerrow, G. Forbes, and S. Woodley. 1996. Biodiversity Implications of Changes in the Quantity of Dead Organic Matter in Managed Forests. *Environmental Reviews* 4(3):238–265.

Ganjegunte, G. K., L. M. Condron, P. W. Clinton, M. R. Davis, and N. Mahieu. 2004. Decomposition and Nutrient Release from Radiata Pine (*Pinus Radiata*) Coarse Woody Debris. *Forest Ecology and Management* 187(2-3):197-211.

Goodburn, J. M., and C. G. Lorimer. 1998. Cavity Trees and Coarse Woody Debris in Old Growth and Managed Northern Hardwood Forests in Wisconsin and Michigan. *Canadian Journal of Forest Reseach* 28:427–438.

Gore, J. A., and W. A. Patterson, III,. 1986. Mass of Downed Wood in Northern Hardwood Forests in New Hampshire: Potential Effects of Forest Management. *Canadian Journal of Forest Research* 16(2):335-339.

Graham, R. L., and K. Cromack Jr. 1982. Mass, Nutrient Content, and Decay Rate of Dead Boles in Rain Forests of Olympic National Park. *Canadian Journal of Forest Research* 12(3):511–521.

Greenberg, C. H. 2002. Response of White-Footed Mice (Peromyscus Leucopus) to Coarse Woody Debris and Microsite Use in Southern Appalachian Treefall Gaps. *Forest Ecology and Management* 164(1-3):57-66.

Griffith, D. M., and C. L. Alerich. 1996. Forest Statistics for Maine, 1995. RB-NE-135, U.S. Forest Service, Northeastern Research Station, Newtown Square, PA.

Grigal, D. F. 2000. Effects of Extensive Forest Management on Soil Productivity. *Forest Ecology and Management* 138(1-3):167-185.

Grigal, D. F. 2004. An Update of Forest Soils. A Technical Paper for a Generic Environmental Impact Statement on Timber Harvesting and Forest Management in Minnesota. Laurentian Energy Agency, Virginia, MN.

Grisez, T. J. 1960. Slash Helps Protect Seedlings from Deer Browsing. *Journal of Forestry* 58(5):385-387.

Grove, S. J. 2002. Saproxylic Insect Ecology and the Sustainable Management of Forests. *Annual Review of Ecology and Systematics* 33(1):1-23.

Gunnarsson, B., K. Nittérus, and P. Wirdenäs. 2004. Effects of Logging Residue Removal on Ground-Active Beetles in Temperate Forests. *Forest Ecology and Management* 201(2-3):229-239.

Gurnell, A. M., K. J. Gregory, and G. E. Petts. 1995. The Role of Coarse Woody Debris in Forest Aquatic Habitats: Implications for Management. *Aquatic Conservation: Marine and Freshwater Ecosystems* 5(2):143-166.

Hacker, J. J. 2005. Effects of Logging Residue Removal on Forest Sites: A Literature Review. Resource Analytics and West Central Wisconsin Regional Planning Commission, Eau Claire, WI.

Hagan, J. M., and S. L. Grove. 1999. Coarse Woody Debris: Humans and Nature Competing for Trees. *Journal of Forestry* 97(1):6-11.

Hale, C. M., J. Pastor, and K. A. Rusterholz. 1999. Comparison of Structural and Compositional Characteristics in Old-Growth and Mature, Managed Hardwood Forests of Minnesota, U.S.A. *Canadian Journal of Forest Research* 29:1479-1489.

Hallett, R. A., and J. W. Hornbeck. 2000. Managing Oak and Pine Stands on Outwash Sands: Protecting Plant Nutrients. *Northern Journal of Applied Forestry* 17(2):57-61.

Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack Jr., and K. W. Cummins. 1986. Ecology of Coarse Woody Debris in Temperate Ecosystems Advances in Ecological Research. Pages 133-302 in A. MacFadyen and E. D. Ford, editors. *Advances in Ecological Research*. Academic Press, London, UK.

Harvey, A. E., M. F. Jurgensen, M. J. Larsen, and R. T. Graham. 1987. Decaying Organic Materials and Soil Quality in the Inland Northwest: A Management Opportunity. GTR-INT-225, U.S. Forest Service, Intermountain Research Station., Ogden, UT.

Heath, L. S., and D. C. Chojnacky. 2001. Down Dead Wood Statistics for Maine Timberlands, 1995. RB-NE-150, Forest Service, Northeastern Research Station, Newtown Square, PA.

Hendrickson, O. Q. 1988. Biomass and Nutrients in Regenerating Woody Vegetation Following Whole-Tree and Conventional Harvest in a Northern Mixed Forest. *Canadian Journal of Forest Research* 18(11):1427–1436.

Hornbeck, J. W., C. W. Martin, R. S. Pierce, F. H. Bormann, G. E. Likens, and J. S. Eaton. 1986. Clearcutting Northern hardwood forests: Effects on Hydrologic and Nutrient Ion Budgets. *Forest Science* 32:667-686.

Hornbeck, J. W., C. T. Smith, Q. W. Martin, L. M. Tritton, and R. S. Pierce. 1990. Effects of Intensive Harvesting on Nutrient Capitals of Three Forest Types in New England. *Forest Ecology and Management* 30(1-4):55-64.

Huntington, T. G. 2005. Assessment of Calcium Status in Maine Forests: Review and Future Projection. *Canadian Journal of Forest Research* 35(5):1109-1121.

Huntington, T. G., and D. F. Ryan. 1990. Whole-Tree-Harvesting Effects on Soil Nitrogen and Carbon. *Forest Ecology and Management* 31(4):193-204.

Idol, T. W., R. A. Figler, P. E. Pope, and F. Ponder. 2001. Characterization of Coarse Woody Debris across a 100 Year Chronosequence of Upland Oak-Hickory Forests. *Forest Ecology and Management* 149(1-3):153-161.

Irland, L. C. 1999. *The Northeast's Changing Forests.* Harvard Forest, Petersham, MA.

Jia-bing, W., G. De-xin, H. Shi-jie, Z. Mi, and J. Chang-jie. 2005. Ecological Functions of Coarse Woody Debris in Forest Ecosystem. *Journal of Forestry Research* 16(3):247-252.

Johnson, D. W., and P. S. Curtis. 2001. Effects of Forest Management on Soil C and N Storage: Meta Analysis. *Forest Ecology and Management* 140(2-3):227-238.

Johnson, D. W., and D. E. Todd, Jr. 1998. Harvesting Effects on Long-Term Changes in Nutrient Pools of Mixed Oak Forest. *Soil Science Society of America Journal* 62(6):1725-1735.

Kappes, H., M. Jabin, J. Kulfan, P. Zach, and W. Topp. 2009. Spatial Patterns of Litter-Dwelling Taxa in Relation to the Amounts of Coarse Woody Debris in European Temperate Deciduous Forests. *Forest Ecology and Management* 257(4):1255-1260.

Keeton, W. S. 2006. Managing for Late-Successional/Old-Growth Characteristics in Northern Hardwood-Conifer Forests. *Forest Ecology and Management* 235(1-3):129-142.

Kelty, M. J., A. W. D'Amato, and P. K. Barten. 2008. Silvicultural and Ecological Considerations of Forest Biomass Harvesting in Massachusetts. Department of Natural Resources Conservation, University of Massachusetts, Amherst, MA.

Kenefic, L. S., and R. D. Nyland. 2007. Cavity Trees, Snags, and Selection Cutting: A Northern Hardwood Case Study. *Northern Journal of Applied Forestry* 24(3):192-196.

Kluyver, H. N. 1961. Food Consumption in Relation to Habitat in Breeding Chickadees. *The Auk* 78(4):532-550.

Kruys, N., and B. G. Jonsson. 1999. Fine Woody Debris Is Important for Species Richness on Logs in Managed Boreal Spruce Forests of Northern Sweden. *Canadian Journal of Forest Research* 29(8):1295–1299.

Kyle, C. J., and C. Strobeck. 2003. Genetic Homogeneity of Canadian Mainland Marten Populations Underscores the Distinctiveness of Newfoundland Pine Martens (Martes Americana Atrata). *Canadian Journal of Zoology* 81(1):57-66.

Laiho, R., and C. E. Prescott. 2004. Decay and Nutrient Dynamics of Coarse Woody Debris in Northern Coniferous Forests: A Synthesis. *Canadian Journal of Forest Research* 34(4):763-777.

Lanham, J. D., and D. C. Guynn, Jr. 1996. Influences of Coarse Woody Debris on Birds in Southern Forests. Pages 101-107 in J. W. McMinn and D. A. Crossley, editors. B*iodiversity and coarse woody debris in southern forests: effects on biodiversity*. U.S. Forest Service. GTR-SE-94.

Loeb, S. C. 1996. The Role of Coarse Woody Debris in the Ecology of Southeastern Mammals. Pages 108-118 in J. W. McMinn and D. A. Crossley, editors. *Biodiversity and coarse woody debris in southern forests: effects on biodiversity*. U.S. Forest Service. GTR-SE-94.

Lynch, J. A., and E. S. Corbett. 1991. Long-Term Implications of Forest Harvesting on Nutrient Cycling in Central Hardwood Forests. Pages 500-518 in L. H. McCormick and K. W. Gottschalk, editors. *8th Central Hardwood Forest Conference*. GTR-NE-148. U.S. Forest Service, Northeastern Forest Experiment Station, University Park, PA.

Mahendrappa, M. K., C. M. Pitt, D. G. O. Kingston, and T. Morehouse. 2006. Environmental Impacts of Harvesting White Spruce on Prince Edward Island. *Biomass and Bioenergy* 30(4):363-369.

Majka, C. G., and D. A. Pollock. 2006. Understanding Saproxylic Beetles: New Records of Tetratomidae, Melandryidae, Synchroidae, and Scraptiidae from the Maritime Provinces of Canada (Coleoptera: Tenebrionoidea). *Zootaxa*(1248):45-68.

Marcus, W. A., R. A. Marston, C. R. Colvard, and R. D. Gray. 2002. Mapping the Spatial and Temporal Distributions of Woody Debris in Streams of the Greater Yellowstone Ecosystem, USA. *Geomorphology* 44(3-4):323-335.

Martin, C., J. Hornbeck, G. Likens, and D. Buso. 2000. Impacts of Intensive Harvesting on Hydrology and Nutrient Dynamics of Northern Hardwood Forests. *Canadian Journal of Fisheries and Aquatic Sciences* 57(S2):19-29.

Mattson, K. G., W. T. Swank, and J. B. Waide. 1987. Decomposition of Woody Debris in a Regenerating, Clear-Cut Forest in the Southern Appalachians. *Canadian Journal of Forest Research* 17(7):712–721.

McCarthy, B. C., and R. R. Bailey. 1994. Distribution and Abundance of Coarse Woody Debris in a Managed Forest Landscape of the Central Appalachians. *Canadian Journal of Forest Research* 24(7):1317–1329.

McCay, T. S., and M. J. Komoroski. 2004. Demographic Responses of Shrews to Removal of Coarse Woody Debris in a Managed Pine Forest. *Forest Ecology and Management* 189(1-3):387-395.

McComb, W. 2003. Ecology of Coarse Woody Debris and Its Role as Habitat for Mammals. Pages 374-404 in Cynthia J. Zabel, Robert F. Anthony, and R. G. Anthony, editors. *Mammal Community Dynamics: Management and Conservation in the Coniferous Forests of Western North America*. Cambridge University Press, Cambridge, UK.

McGee, G. G. 2001. Stand-Level Effects on the Role of Decaying Logs as Vascular Plant Habitat in Adirondack Northern Hardwood Forests. *The Journal of the Torrey Botanical Society* 128(4):370-380.

McGee, G. G., D. J. Leopold, and R. D. Nyland. 1999. Structural Characteristics of Old-Growth, Maturing, and Partially Cut Northern Hardwood Forests. *Ecological Applications* 9(4):1316-1329

McInnis, B. G., and M. R. Roberts. 1994. The Effects of Full-Tree and Tree-Length Harvests on Natural Regeneration. *Northern Journal of Applied Forestry* 11(4):131-137.

McIver, J. D., and L. Starr. 2001. A Literature Review on the Environmental Effects of Postfire Logging. *Western Journal of Applied Forestry* 16(4):159-168.

McNab, W. H., D. T. Cleland, J. A. Freeouf, J. Keys, J.E., G. J. Nowacki, and C. A. Carpenter. 2007. Description of Ecological Subregions: Sections of the Conterminous United States. GTR-WO-76B, U.S. Forest Service, Washington, DC.

Mellina, E., and S. G. Hinch. 2009. Influences of Riparian Logging and in-Stream Large Wood Removal on Pool Habitat and Salmonid Density and Biomass: A Meta-Analysis. *Canadian Journal of Forest Research* 39(7):1280–1301.

MFRC. 2007. Biomass Harvest Guidelines. Minnesota Forest Resources Council, St. Paul, MN.

National Climate Data Center. 2008. *US Climate at a Glance*. http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html, last accessed 10/1/09.

Nord-Larsen, T. 2002. Stand and Site Productivity Response Following Whole-Tree Harvesting in Early Thinnings of Norway Spruce (Picea Abies (L.) Karst.). *Biomass and Bioenergy* 23(1):1-12.

Nyland, R. D., D. G. Ray, R. D. Yanai, R. D. Briggs, L. Zhang, R. J. Cymbala, and M. J. Twery. 2000. Early Cohort Development Following Even-Aged Reproduction Method Cuttings in New York Northern hardwood forests. *Canadian Journal of Forest Research* 30(1):67-75.

Olsson, B. A., H. Staaf, H. Lundkvist, J. Bengtsson, and R. Kaj. 1996. Carbon and Nitrogen in Coniferous Forest Soils after Clear-Felling and Harvests of Different Intensity. *Forest Ecology and Management* 82(1-3):19-32.

Patrick, D. A., J. Hunter, Malcolm L., and A. J. K. Calhoun. 2006. Effects of Experimental Forestry Treatments on a Maine Amphibian Community. *Forest Ecology and Management* 234(1-3):323-332.

Pierce, R. S., J. W. Hornbeck, W. C. Martin, L. M. Tritton, T. C. Smith, A. C. Federer, and H. W. Yawney. 1993. Whole-Tree Clearcutting in New England: Manager's Guide to Impacts on Soils, Streams, and Regeneration. GTR-NE-172, U.S. Forest Service, Northeastern Forest Experiment Station, Radnor, PA.

Richardson, J., R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. 2002. *Bioenergy from Sustainable Forestry: Guiding Principles and Practice*. Kluwer Academic Publishers, Hingham, MA.

Roskoski, J. 1980. Nitrogen Fixation in Hardwood Forests of the Northeastern United States. *Plant and Soil* 54(1):33-44.

Roskoski, J. P. 1977. *Nitrogen Fixation in Northern hardwood forests Forests*. Yale University, New Haven, CT.

Sass, G. G. 2009. Coarse Woody Debris in Lakes and Streams. Pages 60-69 in G. E. Likens, editor. *Encyclopedia of Inland Waters*. Academic Press, Oxford.

Smith, C. Y., M. T. Moroni, and I. G. Warkentin. 2009. Snag Dynamics in Post-Harvest Landscapes of Western Newfoundland Balsam Fir-Dominated Boreal Forests. *Forest Ecology and Management* 258(5):832-839.

Smith Jr, C. T., M. L. McCormack Jr, J. W. Hornbeck, and C. W. Martin. 1986. Nutrient and Biomass Removals from a Red Spruce - Balsam Fir Whole-Tree Harvest. *Canadian Journal of Forest Research* 16(2):381-388.

Taylor, A. R., J. R. Wang, and H. Y. H. Chen. 2007. Carbon Storage in a Chronosequence of Red Spruce (Picea Rubens) Forests in Central Nova Scotia, Canada. *Canadian Journal of Forest Research* 37(11):2260–2269.

Tritton, L. M. 1980. *Dead Wood in the Northern Hardwood Forest Ecosystem*. Yale University, New Haven, CT.

Tritton, L. M., C. W. Martin, J. W. Hornbeck, and R. S. Pierce. 1987. Biomass and Nutrient Removals from Commercial Thinning and Whole-Tree Clearcutting of Central Hardwoods. *Environmental Management* 11(5):659-666.

Tritton, L. M., and T. G. Siccama. 1990. What Proportion of Standing Trees in Forests of the Northeast Are Dead? *Bulletin of the Torrey Botanical Club* 117(2):163-166.

Tubbs, C. H., R. M. DeGraaf, M. Yamasaki, and W. M. Healy. 1987. Guide to Wildlife Tree Management in New England Northern hardwood forests. GTR-NE-118, U.S. Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

Vanderwel, M. C., J. R. Malcolm, and S. M. Smith. 2006a. An Integrated Model for Snag and Downed Woody Debris Decay Class Transitions. *Forest Ecology and Management* 234(1-3):48-59.

Vanderwel, M. C., J. R. Malcolm, S. M. Smith, and N. Islam. 2006b. Insect Community Composition and Trophic Guild Structure in Decaying Logs from Eastern Canadian Pine-Dominated Forests. *Forest Ecology and Management* 225(1-3):190-199.

Watmough, S. A., and P. J. Dillon. 2003. Base Cation and Nitrogen Budgets for Seven Forested Catchments in Central Ontario, 1983-1999. *Forest Ecology and Management* 177(1-3):155-177.

Weaver, J. K., L. S. Kenefic, R. S. Seymour, and J. C. Brissette. 2009. Decaying Wood and Tree Regeneration in the Acadian Forest of Maine, USA. *Forest Ecology and Management* 257(7):1623-1628.

Westveld, M. 1956. Natural Forest Vegetation Zones of New England. *Journal of Forestry* 54(5):332-338.

Whiles, M. R., and J. W. Grubaugh. 1996. Importance of Coarse Woody Debris to Southern Forest Herpetofauna. Pages 94-100 in J. W. McMinn and D. A. Crossley, editors. *Biodiversity and coarse woody debris in southern forests: effects on biodiversity.* U.S. Forest Service. GTR-SE-94.

White Mountain National Forest. 2005. Final Environmental Impact Statement. U.S. Forest Service, Laconia, NH.

Wilson, B. F., and B. C. McComb. 2005. Dynamics of Dead Wood over 20 Years in a New England Oak Forest. Canadian *Journal of Forest Research* 35:682–692.

Woodley, S. 2005. Snag and Cavity Tree Retention. Pages 61-64 in M. G. Betts and G. J. Forbes, editors. *Forest Management Guidelines to Protect Native Biodiversity in the Greater Fundy Ecosystem.* New Brunswick Co-operative Fish and Wildlife Research Unit, University of New Brunswick, Fredericton, NB.

Yanai, R. D., J. D. Blum, S. P. Hamburg, M. A. Arthur, C. A. Nezat, and T. G. Siccama. 2005. New Insights into Calcium Depletion in Northeastern Forests. *Journal of Forestry* 103(1):14-20.

Yowhan Son. 2001. Non-Symbiotic Nitrogen Fixation in Forest Ecosystems. *Ecological Research* 16(2):183-196.

Zell, J., G. Kändler, and M. Hanewinkel. 2009. Predicting Constant Decay Rates of Coarse Woody Debris—a Meta-Analysis Approach with a Mixed Model. *Ecological Modelling* 220(7):904-912.

APPENDIX 4–B

REVISED ASSESSMENT OF BIOMASS HARVESTING AND RETENTION GUIDELINES

Alexander M. Evans, Robert T. Perschel, and Brian Kittler

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1. Introduction

Interest in removing low-grade wood from forests has increased because of rising fossil fuel costs, concerns about carbon emissions from fossil fuels, and the risk of uncharacteristic wildfires.[1, 19] Most existing forest practice rules and recommendations did not anticipate this increased extraction of woody biomass and offer no specific guidance on how much removal is healthy for ecosystems. Intensification of biomass utilization, particularly for energy and fuel needs, presents a range of potential environmental risks.[31, 29] This report provides a review of guidelines put forth by states and other entities to avoid these environmental risks and promote the ecological sustainability of forest biomass utilization, and can inform a similar process to develop guidelines in Massachusetts.

1a. Woody Biomass

While definitions of biomass are usually similar, there can be surprising differences. For instance, the definition of biomass in New Brunswick, Canada's guidelines excludes pulpwood fiber from whole-tree chipping.[42] Technically, the term woody biomass includes all the trees and woody plants in forests, woodlands, or rangelands. This biomass includes limbs, tops, needles, leaves, and other woody parts.[44] In practice, woody biomass usually refers to material that has historically had a low value and cannot be sold as timber or pulp. Biomass harvesting might even remove dead trees, down logs, brush, and stumps.[37] Markets determine which trees are considered sawtimber material and which are relegated to the low-value biomass category. Changing markets and regional variations determine the material considered biomass, but in general it is a very low quality product. In some cases, woody biomass is defined by how the material is used. For example, in Pennsylvania any material burned for energy is defined as biomass.[46]

In this report, the term **biomass** refers to *vegetation removed from the forest, usually logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-quality products such as sawtimber.* This report does not discuss biomass from agricultural lands and short-rotation woody biomass plantations.

Photo: Zander Evans

Biomass can be removed in a number of ways. Some harvests remove only woody biomass, some combine the harvest of sawtimber or other products with biomass removal, and some remove biomass after other products have been removed. This report focuses on what remains in the forest after harvest and not on the type of harvest. The goal is to ensure the forest can support wildlife, provide clean water, sequester carbon, protect forest soil productivity, and continue to produce income after a biomass harvest or repeated harvests. In some regions, current wood utilization is such that no woody material is available for new markets such as energy. For these high-utilization areas, following biomass guidelines may result in more biomass being left in the forest.

1b. Coarse Woody Material

Woody material is sometimes divided into coarse woody material (CWM), fine woody material (FWM), and large woody material. CWM has been defined as being more than 6 inches in diameter at the large end and FWM as less than 6 inches in diameter at the large end.37 The U.S. Forest Service defines CWM as down dead wood with a small-end diameter of at least 3 inches and a length of at least 3 feet and FWM as having a diameter of less than 3 inches.62 FWM tends to have a higher concentration of nutrients than CWM. Large downed woody material, such as logs greater than 12 inches in diameter, is particularly important for wildlife. In this report, we use the term **downed woody material (DWM)** to encompass all three of these size classes, but in some circumstances we discuss a particular size of material where the piece size is particularly important.

1c. Why "Biomass" Guidelines?

Good biomass harvesting practices can enhance and improve forest land; poor practices can damage and devalue it.46

In the United States, forestry on private and state forests is regulated primarily at the state level. At least 276 state agencies across the country have some oversight of forestry activities, including agencies focused on forestry and other state agencies, such as wildlife or environmental protection.[17] Federal law requires states to address non-point source pollution of waterways. All 50 states have Best Management Practice (BMP) programs that are intended to protect water quality and other values. The programs usually include sections on timber harvesting, site preparation, reforestation, stream crossings, riparian management zones, prescribed burning and fire lines, road construction and maintenance, pesticides and fertilizers, and wetlands. Programs in states vary from laws that prescribe mandatory practices to states that use voluntary BMPs and education and outreach programs. These programs can be categorized in four ways: non-regulatory with enforcement, regulated, and combination of regulatory and not regulatory. In the northeast, Massachusetts and Connecticut are considered regulated, Vermont and New Hampshire are non-regulated with enforcement and Rhode Island, New York, and Maine use a combination of approaches. These programs are routinely monitored and literature suggests that when these BMPs are properly implemented they do protect water quality.[51] With so much existing regulation, why are additional biomass harvesting guidelines necessary? Reasons for biomass harvesting guidelines are likely to mirror the reasons forestry is regulated in general, which include[16]:

- general public anxiety over environmental protection,
- the obligation to correct misapplied forestry practices,
- the need for greater accountability,
- growth of local ordinances,
- landscape-level concerns, and
- following the lead of others.

Photo: Zander Evans

More specifically, biomass harvesting guidelines are designed to fill the gaps where existing BMPs and forest practice regulations may not be sufficient to protect forest resources under new biomass harvesting regimes. In other words, BMPs were developed to address forest management issues at a particular point in time; as new issues emerge, new guidelines may be necessary. Existing guidelines did not anticipate the increased rate or new methods of biomass removal and offer no specific guidance on the amount of extraction that is acceptable for meeting a range of forest management objectives. For example, Pennsylvania's old BMPs encouraged operators "to use as much of the harvested wood as possible to minimize debris," while the new guidelines recommend leaving "15 to 30 percent of harvestable biomass as coarse woody debris."[46] Michigan's guidelines point out that while the state "has a rich history of utilizing woody biomass for bioenergy and biobased products such as lumber, pulp and paper, composites, heat and electrical generation," as "market opportunities expand for woody biomass, it is crucial that harvesting and removal of woody biomass be done using sustainable forest management principles and practices that are ecologically, economically, and socially appropriate."[36] Concerns about long-term site productivity, biodiversity, and wildlife populations drove the Minnesota state legislature to call for biomass harvesting guidelines, and the resulting guidelines are intended to be implemented in close conjunction with the existing Minnesota forestry guidelines, which cover a range of additional management considerations.[37] More generally, biomass guidelines focus on DWM levels, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and, in some cases, other issues. For example, Maine's guidelines focus "on the amount of biomass that should be left on-site after harvest and the effect on soil productivity, water quality, and biodiversity."[7]

1d. An Examination of Current Guidelines

This report reviews the biomass harvesting or retention guidelines from New York and New England, other states with specific biomass guidance, parts of Canada, Northern European counties, and other organizations, including the U.S. federal government and certification groups. We have grouped New York and the New England states together to offer a snapshot of the current situation in states geographically near Massachusetts. Maryland, Minnesota, Missouri, Michigan, Pennsylvania, Wisconsin, and California are also covered, because of their forest practices guidance on biomass harvest and retention. In some states guidelines are still under review at the time of this writing and subject to change. Readers are encouraged to use the links in Appendix II to check the latest drafts of the guidelines.

The examples in this report detail the status of rules and recommendations for removing biomass from our forests. Entities interested in addressing concerns about biomass removal have taken at least three different approaches. One is to verify that existing forest practice regulations cover the issues raised by biomass harvests, obviating the need for new guidelines. In instances where existing rules or recommendations are found to be insufficient, some entities—including Minnesota, Missouri, Pennsylvania, Wisconsin, and Maine—have taken a second type of approach and chosen to craft separate biomass guidelines that augment existing forest practice guidance. In the third case, entities such as the Forest Stewardship Council (FSC) have chosen to address concerns particular to biomass harvests by revising existing rules or recommendations.

The existing guidelines cover topics such as dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, silviculture, and disturbance. Appendix I lists the commonly used subtopics for each and identifies which are covered in a given set of guidelines. In some cases, a subtopic is noted as covered because it appears in another set of forestry practice rules or recommendations instead of that state's biomass guidelines. The list of subtopics was developed from section headings in all the various existing guidelines and is similar to other criteria for sustainable production and harvest of forest biomass for energy.[31] It should be noted that each set of guidelines takes a slightly different approach, addressing topics with a greater or lesser degree of specificity. The precepts of sustainable forest management call for identifiable criteria and indicators, such as those identified through the Montreal Process, for the purpose of benchmarking and measuring forest practices. The critique that follows does not always address why topics are covered with more or less specificity, but presumes that more specificity will increase the likelihood that guidelines will encourage sustainable management.

2. BIOMASS RETENTION GUIDELINES FOR TIMBER HARVESTING IN NEW YORK AND NEW ENGLAND

2a. Maine

In Maine, "guidelines specific to woody biomass retention are missing from existing best management practices and regulations."[40] Therefore, the state undertook a collaborative effort between the Maine Forest Service, the University of Maine, and the Trust to Conserve Northeast Forestlands to develop woody biomass retention guidelines. Participating committee members included Manomet Center for Conservation Sciences, the Forest Guild, the Maine Forest Products Council, and other forestry professional and environmental organizations. After a multi-year process and several drafts, *Consideration and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine* was released in 2010.[7] The project's goal was to address the growing interest in woody biomass and concerns about long-term sustainability of biomass harvesting by developing guidelines for the retention of woody biomass. The Maine guidelines define woody biomass as "logging residues, previously un-merchantable stems, and other such woody material harvested directly from the forest typically for the purposes of energy production."[40] These new guidelines augment the current Water Quality BMPs, which are effectively applied in most harvests (77 percent of stream crossings and 89 percent of approaches to the crossings[39]).

The biomass harvesting recommendations report includes an extensive background section and literature review, including three key documents:

- *Best Management Practices for Forestry,*[38]
- *Site Classification Field Guide,*[9]
- *Biodiversity in the Forests of Maine: Guidelines for Land Management.*[18]

It also includes appendices that summarize regional recommendations pertaining to wildlife trees and biomass harvesting. The background section covers soil productivity, water quality, and forest management, as well as forest biodiversity; at the end of each section are voluntary guidelines. In earlier drafts, the voluntary guidelines offered after each section were more specific and stringent, but the final version lacks specific targets. Earlier drafts referred to the entire effort as "Guidelines," but the reframing of the title indicates the struggle the committee members had in agreeing on specific targets and the vagueness of the final product. For example, the voluntary guidelines for soils indicate forest litter should be left on-site "to the extent possible" and that operators should "minimize removal" of FWM on low-fertility sites.

This lack of specificity is found in other sections as well. The commentary on setting targets for the Forest Biodiversity section helps shed light on the decision-making dynamics that led to the dilution of the final product. The background information for the Forest Biodiversity section draws heavily on *Biodiversity in the Forests of Maine*. This report, a comprehensive manual outlining recommended guidelines for maintaining biodiversity in the forests of Maine, was the culmination of a multi-year process in the 1990s that included a wide range of stakeholders, including industry representatives, forest professionals, and environmental organizations. Originally published by Flatebo and colleagues[22], it was updated by Elliot.[18] Although the final version of the current biomass retention report utilizes the recommendations from the biodiversity report as background information and indicates that woody biomass harvesting practices "will have to comply with established recommendations for biodiversity as defined for non-biomass harvests,"[7] the specific targets listed in the biodiversity report are never incorporated as guidelines. The report indicates that since there was "not widespread acceptance of those guidelines within Maine's forest industry, specific targets for maintenance of site-level biodiversity are not included" in the relevant section.[7]

The result for the Forest Biodiversity section is that the Voluntary Guidelines call for leaving "as much fine woody material as possible" without the specific guidelines for DWM retention found in some other state guidelines. The guidelines also call for leaving "some wildlife trees" without incorporating targets for numbers of trees per acre suggested in *Biodiversity in the Forests of Maine*. The report indicates that this vagueness in the guidelines reflects the challenges of setting specific targets at site levels[18] and that although science can direct selection of biological indicators, it is still weak in selecting specific target levels.[24]

2b. New Hampshire

While New Hampshire currently has no specific biomass harvesting guidelines, existing recommendations and rules address the major biomass harvesting topics. New Hampshire's Slash Law (RSA 227-J:10) focuses on "debris left after a timber harvest" and states that "these branches, leaves, stems, unmerchantable logs, and stumps may take several years to decompose. Slash represents a fire hazard and, often, a messy appearance." The Slash Law sets a limit on the height of slash that can be left on-site, but does not set any minimum to retain on site.


Photo: Christopher Riely

New Hampshire's Basal Area Law (RSA 227-J:9) states that no more than 50 percent of the basal area can be cut near streams, water bodies, and public roads. Intensive biomass removal may decrease this law's ability to prevent erosion, provide wildlife habitat, protect stream temperature and aquatic life, and preserve the aesthetics of the landscape, because removal of DWM is not regulated by a basal area restriction. In New Hampshire, BMPs are voluntary, but the guide *Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire* includes sections on soil productivity, DWM, and retention of forest structures for wildlife habitat.[13] *Good Forestry* does not provide specific guidance on retention of tops and limbs, though it does recommend leaving "some cull material" in the woods after a biomass harvest. The section on soil productivity provides recommendations that would limit biomass removal on sites with nutrient-poor soils:

- Identify low fertility soils from maps and descriptions.
- Use bole-only harvesting (taking out the main portion of tree only, leaving branches and limbs in the woods) on low-fertility soils, or where fertility is unknown, as a precaution against nutrient loss.
- If whole-tree harvesting hardwoods, try to plan harvests during leaf-off periods to retain leaves and nutrients on site.
- Limit disruption of soil organic layers except when needed to accomplish silvicultural objectives (such as regeneration of species that need a bare mineral soil seedbed).[13]

Similarly, the Habitat section recommends retention of cavity trees and snags:

- In areas under uneven-aged management, retain a minimum of 6 secure cavity and/or snag trees per acre, with one exceeding 18 inches DBH and 3 exceeding 12 inches DBH. In areas lacking such cavity trees, retain trees of these diameters with defects likely to lead to cavity formation.
- In areas under even aged management, leave an uncut patch for every 10 acres harvested, with patches totaling 5 percent of the area. Patch size may vary from a minimum of 0.25 acre. Use cavity trees exceeding 18 inches DBH or active den trees as nuclei for uncut patches. Remember, the larger the tree, the more species that can use it. Riparian and other buffers can help to satisfy this goal.
- Retain live trees with existing cavities.[13]

The *Good Forestry in the Granite State* guide also has recommendations for retention of DWM:

- Avoid damaging existing downed woody debris, especially large (18+ inches) hollow or rotten logs and rotten stumps during harvesting operations (including tree falling, skidding, and road and skid trail layout).
- Leave cull material from harvested trees, especially sound hollow logs, in the woods. Some cull material should be left behind during whole-tree or biomass harvesting operations that may otherwise utilize this material. Large pieces of cull material bucked out on the landing should be returned to the woods.
- Avoid disrupting downed logs in and adjacent to streams, ponds, and wetlands.

- Avoid disrupting upturned tree roots from May to July to protect nesting birds.
- Maintain or create softwood inclusions in hardwood stands to provide a supply of longer-lasting down woody material.[13]

A revision of Good Forestry in the Granite State is currently underway and the recommendations for DWM in the draft are similar to the existing language.

2c. Vermont

Although Vermont's guide to *Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont* is in its ninth printing, there is very little in the guide that would affect biomass harvesting or retention.[60] The guide's intent is to prevent discharges of mud, petroleum, and wood debris from getting into waterways. These BMPs are not mandatory unless a landowner is participating in Vermont's Use Value Act. The state's two wood-powered power plants in Burlington and Ryegate are required by the Public Service Board to ensure that their wood supply comes from sales with a harvest plan cleared by the Vermont Department of Forests, Parks and Recreation. The main focus of the review of harvest plans is to protect deer wintering areas. Related rules include the Heavy Cutting rules (Act 15), which require clearcuts (a reduction of basal area below the C-level) larger than 40 acres to have a permit (Title 10 V.S.A. Chapter 83, Section 2622). Another regulation that has some relevance to biomass harvesting is the requirement that whole-tree chip harvesters obtain a license (Title 10 V.S.A. Chapter 83, Section 2648).

An act of the Vermont Legislature created a Biomass Energy Development Working Group in 2009. That group is meeting regularly in a two-year initiative to address the major charges of (1) enhancing and developing Vermont's biomass industry while (2) maintaining forest health. As part of its process, subgroups are addressing issues such as economic incentives, supply models, available technology, and workforce availability. A Forest Health subgroup will consider guidelines for retention of woody biomass, forest health indicators, and emerging research on carbon and biomass harvesting issues.

2d. New York

New York's forest practice regulations are based the Environmental Conservation Law (§ 9-0105), though the regulations appear to only cover prescribed fires. *The Best Management Practices for Water Quality* has no recommendation about retention of DWM, snags, or other elements specific to biomass harvesting.[45] These BMPs cover planning, landings, stream crossings, roads and trails, vernal pools, erosion control techniques, and post-harvest considerations. This document is under revision and will include expanded sections on riparian and wetland zone management but nothing on the ecological or silvicultural aspect of biomass harvesting. New York currently has no immediate plans to develop biomass harvesting guidelines. They are monitoring developments in other states and a biomass study now taking place at the Adirondack Research Consortium.

However, when New York initiated its renewable portfolio standard, it established an eligibility procedure for electrical power generators utilizing forest biomass. The resulting requirements are modeled after Vermont's and include procurement plans for each facility to include forest management plans for source forests and harvest plans filed for all harvests. Adherence to these standards is monitored periodically by state foresters. New York varied slightly from Vermont's approach by providing exemptions to properties that are accredited by FSC, Sustainable Forestry Initiative, or Tree Farm.

2e. Rhode Island

Rhode Island's BMP guidance is encapsulated in the document *Rhode Island Conservation Management Practices Guide*.[12] The Guide includes water-quality protections such as filter strips between harvested areas and streams or ponds. Rhode Island does require the registration of "woods operators" with the Division of Forest Environment and notification of intent to harvest timber (RI State Statues, Title 2, Chapter 2-15, Sections 1 and 2). Rhode Island has no current intentions to develop biomass harvesting guidelines, although it is aware of the issue and may address it in the future.

2f. Connecticut

Connecticut's BMP field guide was revised in 2007 and focuses specifically on water-quality issues.[15] This guide, like New York's and Rhode Island's, has little effect on biomass removals or DWM retention.[12, 15, 45] Connecticut is now seeking funding to address biomass harvesting guidelines. Current BMPs recommend keeping slash out of water bodies and vernal pools. Connecticut's BMPs do suggest that "brush and slash may be placed in skid trails and on slopes to slow water flow and retain sediment."[15] One layer of protection is the state's certification program for foresters and loggers. Connecticut is watching the development of the biomass market carefully and would like to have some guidelines in place. It is now looking for funding for developing guidelines, possibly through a joint project between the state forestry department and the Connecticut Forest and Parks Association.

3. Review of State Biomass Harvesting and Retention Guidelines

3a. Michigan Woody Biomass Harvesting Guidance

Since 2008, the Michigan Department of Natural Resources has worked with a stakeholder group drawn from academia, environmental groups, forest industry, and state and federal agencies to develop biomass harvesting guidelines.[36] These guidelines were designed to be used in conjunction with Michigan's *Sustainable Soil and Water Quality Practices on Forest Land* manual.[35] They emphasize that "not every recommendation listed in this guidance can or should apply to every situation." While the Michigan guidelines provide a list of scientific references, there are no specific citations to support the retention or removal of forest biomass.

Topics such as riparian zones and pesticide use are covered by *Sustainable Soil and Water Quality Practices* and not in the biomass harvesting guidelines. Though brief, Michigan's biomass guidelines, in combination with *Sustainable Soil and Water Quality Practices*, cover most of the major biomass harvesting topics (see Appendix I). However, there is little guidance on retention of snags. Michigan's guidelines also lack specificity in some areas. For example, they suggest retention of anywhere from one-sixth to one-third of material less than 4 inches in diameter from harvested trees.

3b. Minnesota: Biomass Harvesting Guidelines for Forestlands

The Minnesota state legislature directed the Minnesota Forest Resources Council (MFRC) and the Minnesota Department of Natural Resources (DNR) to develop guidelines for sustainably managed woody biomass.[37] The goal of the guidelines was to help natural resource managers, loggers, equipment operators, contractors, and landowners make decisions about biomass harvesting. With the support of the DNR's Ecological Services, Fisheries and Wildlife, and Forestry divisions, the MFRC directed the guideline development process. The 12-member interdisciplinary technical committee developed separate guidelines for brushland as well as for forestland. The technical committee reflected a range of expertise deemed pertinent to the development of these guidelines, including soil science, wildlife biology, hydrology, forest management, and silviculture. Meeting summaries were provided online, and the committee's work was peer-reviewed and open to public comment. Minnesota's biomass harvesting guidelines were crafted to be part of the MFRC's 2005 forest management guidebook, *Sustaining Minnesota Forest Resources*, and the existing guidelines were integrated into the new biomass recommendations.

Minnesota's biomass harvesting guidelines are rooted in precepts of ecological forestry. For example, the guidelines recommend emulating natural disturbances with silviculture and maintaining biological legacies after harvest. The guidelines make the case that, in Minnesota, biomass harvesting increases the disparity between managed stands and their natural analogs because it reduces the biological legacies left after harvest, such as slash and fallen logs. The guidelines cover almost all of the topics and subtopics related to biomass harvesting we considered in our analysis (see Appendix I). The only topics not obviously included or referenced were aesthetics, forest diseases, and land conversion.

Photo: Eli Sagor

A recent field test—an experimental biomass harvest—suggests that the harvesting practices utilized for biomass harvest in Minnesota can remove woody biomass without significant negative impacts on snags and DWM. The test harvest had a small effect on the number of snags and on the amount of DWM. Reductions in DWM were small (2 tons per acre or less) and one site showed an increase in DWM.[5] In addition, of the seven test sites where snags were measured, only three had a lower number of snags after harvest.[5]

3c. Missouri: Best Management Practices for Harvesting Woody Biomass

The catalyst for the development of biomass harvesting guidelines in Missouri was state legislation introduced in February 2007 concerning cellulosic ethanol.[34] In response to the lack of BMPs for biomass harvests, the Top of the Ozarks Resource Conservation and Development (RC&D), in partnership with Big Springs RC&D, Bootheel RC&D, the Eastern Ozarks Forestry Council, and the Missouri Department of Conservation, applied for and received a grant from the Northeastern Area State and Private Forestry branch of the U.S. Forest Service to develop BMPs for biomass harvesting. The BMPs development process continued to emphasize participation through a stakeholder meeting for a cross-section of interested parties to discuss issues and possible criteria to be addressed in the BMPs for harvesting woody biomass. A technical committee brought expertise on soil science, wildlife biology, hydrology, forest management, and silviculture to the process. Meeting announcements and notes were provided online to allow for transparency in the development of BMPs.

Photo: Zander Evans

The Missouri guidelines cover the major biomass harvesting topics (see Appendix I). Subtopics not covered in the Missouri guidelines include regeneration, removal of litter and forest floor, and fuel reduction. A section on pesticides was included in an early version of the biomass guidelines, but was later dropped because of its lack of relevance to biomass.

3d. Pennsylvania: Guidance on Harvesting Woody Biomass for Energy

Pennsylvania's guidelines are a direct result of increased interest in woody biomass for energy. The passage of Pennsylvania's Alternative Energy Portfolio Standards Act (Act 213 of 2004) helped drive that interest by requiring "all load-serving energy companies in the state to provide 18 percent of their electricity using alternative sources by the year 2020." In response to the interest in using Pennsylvania's forests to help meet alternative energy goals, the Department of Conservation and Natural Resources (DCNR) created biomass harvesting guidelines, intending to balance the need for alternative energy sources with the need to protect forest resources for all citizens and future generations. Pennsylvania's guidelines include short-term rotational biofuel crops that might not traditionally fall under forest management guidelines.

Harvests on state forests are required to follow Pennsylvania's guidelines. The guidelines also supply recommendations for private lands; these are drawn from *Best Management Practices for Pennsylvania's Forests*, which was published by the Forest Issues Working Group in 1997. However, the new biomass guidelines did not draw on wider stakeholder participation, in part because of the time pressure to produce guidelines before forest-based energy projects were initiated. Pennsylvania's guidelines are also unusual in that they include comments on biomass policy and a supply assessment. For example, the guidelines suggest that facilities requiring 2,000 tons per year are better suited to Pennsylvania than larger facilities. The guidelines also make a case for woody biomass as a carbon-neutral fuel source.

Since Pennsylvania's state forestlands are certified as meeting the standards of FSC, their biomass harvesting guidelines directly reference FSC standards. Pennsylvania's DCNR uses the FSC's Appalachia Regional Standard, but the state biomass harvesting guidelines provide greater specificity on woody biomass removals. For example, the FSC standard requires that "measures to protect streams from degradation of water quality and/or their associated aquatic habitat are used in all operations." The Pennsylvania biomass guidelines extend this idea by adding "biomass harvesting of any materials along stream and river banks or along bodies of water is unacceptable." The Pennsylvania biomass guidelines cover the range of potential biomass harvesting subtopics. Non-point source pollution and pesticides are not dealt with in the biomass harvesting guidelines, but these are covered in general forestry guidelines for Pennsylvania.

3e. Maryland: Development of Forest Biomass Harvesting Guidelines

Maryland is currently in the process of developing biomass harvesting guidelines. The Pinchot Institute for Conservation is facilitating a committee of individuals representing state forestry, environmental and energy agencies, cooperative extension, private landowners, non-profit conservation organizations, and local governments. Specialists in ecology, forest hydrology, forestry, economics, and other disciplines are included on the advisory committee. The guidelines will address the charge of the *Maryland Climate Action Plan*, which states, "All biomass will be sustainably harvested without depriving soils of important organic components for reducing erosion, but will maintain soil nutrient structure, and will not deplete wildlife habitat or jeopardize future feedstocks in quantity or quality." As such, Maryland's biomass guidelines will address the protection of forest soils, water quality and aquatic resources, wildlife habitat and biodiversity, and silviculture and vegetation management. Other topics may also be included in the final version of the guidelines document. This guideline document is also linked to a technical support document that addresses the potential impacts associated with forest biomass harvesting in Maryland and a review of relevant statutes and regulatory and non-regulatory programs that operate within the state.

3f. Wisconsin's Forestland Woody Biomass Harvesting Guidelines

Wisconsin's biomass guidelines were motivated by new price incentives to produce wood-based renewable energy and concerns about the environmental impacts of increased woody biomass removal.[26] The Wisconsin Council on Forestry created an advisory committee with members from tribal, state, non-profit, and private forestry organizations. The guidelines were also reviewed by subject experts.

The guidelines cover much of the same ground as the other state guidelines (Table 1). They take advantage of the existing guidance provided by Wisconsin's *Silviculture and Forest Aesthetics Handbook and Forestry Best Management Practices for Water Quality*. Issues such as regeneration, water quality, and aesthetics are dealt with in the existing manuals rather than the new biomass guidelines. A major focus of the Wisconsin guidelines is the identification of soil types, such as shallow, sandy, or wetland, that are most at risk of nutrient depletion.

Photo: Zander Evans

3g. California Forest Practice Rules

California has some of the most comprehensive forest management regulations in the world. While there are currently no rules designed to specifically address intensive removal of forest biomass, the existing regulations address all of the main topics and most of the subtopics of woody biomass removal (Appendix I). For example, the *California Forest Practice Rules* point out that snags, den trees, and nest trees are a habitat requirement for more than 160 species and play a vital role in maintaining forest health. The importance of snags translates into regulations that require retention of all snags except where specific safety, fire hazard, insect, or disease conditions require they be felled.[11]

California's regulations demonstrate the tradeoffs between the ecological benefits and the potential fire hazards of retaining dead wood on-site in fire-adapted ecosystems.[10] For example, the *California Forest Practice Rules* emphasize the ecological importance of DWM for soil fertility, moisture conservation, and the support of microorganisms, but regulations dictate slash removal rather than retention. However, in riparian areas the Forest Practice Rules require operations to "protect, maintain, and restore trees (especially conifers), snags, or downed large woody debris" that provide stream habitat.[11]

A technical team of the Interagency Forestry Working Group is currently reviewing whether forest practice regulations in the state assure the ecological sustainability of forest biomass production and harvest. This technical team will also examine the carbon sequestration and storage impacts of both forest management and catastrophic fires.

4. BIOMASS GUIDELINES AND POLICY IN CANADA

As with state biomass guidelines in the U.S., woody biomass policy and guidelines in Canada are designed and implemented at the provincial level, not by the central government. Another similarity between the U.S. and Canada is the shift from a greater proportion of private holdings in the East to greater government (i.e., Crown) land ownership in the West. While provincial biomass guidelines would apply to public land and not private land, private landowners in eastern Canada are asking provincial governments for guidance on how best to manage their private land for bioenergy.

An overview of biomass policy and guidelines from east to west in Canada reveals variation similar to that in the United States.[48] Nova Scotia has formed a multi-stakeholder biomass committee of government, industry, and environmental groups that is discussing guidelines. There is currently a two-year moratorium on harvesting logging residue there to allow for input from this committee and then the creation of a government policy. In New Brunswick, the Department of Natural Resources has prepared draft guidelines on forest biomass harvesting. New Brunswick's guidelines take advantage of a decision support tool for sustainable biomass allocation that evolved from a model used to predict impacts of atmospheric deposition. The guidelines exclude harvests on high-risk (low-nutrient) areas, and harvest and silviculture planning remain separate processes guided by the Crown land management framework. The policy calls for biomass harvesting sustainability to be assessed over an 80-year time period, which is "equivalent to the life span of an average forest stand."[42] The New Brunswick guidelines define biomass such that the guidelines do not apply to pulpwood fiber from whole-tree chipping.

Like New Brunswick, Quebec is in the process of developing biomass guidelines based on soil properties. Ontario's policy establishes objectives such as "to improve the utilization of forest resources by encouraging the use of forest biofibre for the production of energy and other value-added bioproducts." However, the management and sustainable use of forest biomass is still guided by existing legislation (e.g., the Crown Forest Sustainability Act and its associated regulated manuals and procedures). In British Columbia, biomass removals during current forest practices (e.g., full-tree with processing at roadside) are already covered under the Forest and Range Practices Act (FRPA). Regulations under the FRPA require the retention of at least 1.6 logs per acre (at least 16 feet in length and 12 inches in diameter on the coast and 6.5 feet in length and 3 inches in diameter in the interior; FRPA §68). In addition, a strategic plan for increased biomass removals is being developed, and scientists have begun to collate data that will be used to formulate guidelines for increased slash harvesting.

A 2008 conference entitled "The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policies," hosted by Canada's Sustainable Forest Management Network, helped set the stage for future policy development by providing an overview of existing research on biodiversity,[33] site productivity considerations for biomass harvests,[55] and existing knowledge gaps.[56]

5. BIOMASS GUIDELINES AND POLICY IN NORTHERN EUROPE

Woody biomass provides a large contribution to the heat of Northern Europe and is also utilized for co-firing with coal and for straight biopower facilities in some countries such as the Netherlands and in the UK. Though management guidelines are similar across Northern Europe, their integration under the broader forest management policy is more varied. For example, the UK and Finland have determined that biomass harvesting guidelines work best as independent reference documents to help guide practitioners, whereas Austria and Sweden have integrated biomass harvesting protocols directly into their broader forest management protocols and regulations. The following section will review the approach that countries in Northern Europe have taken to biomass harvesting standards.

5A. Sweden

The use of forest-based bioenergy in Sweden increased in the 1980s as a result of growing concern over a reliance on imported oil and nuclear power. In 1991, the Swedish government introduced a carbon tax on fossil fuels used for heat and transportation. Since this time, the use of forest-based biomass for energy generation has more than doubled and forest-based bioenergy now accounts for more than 27 percent of total Swedish energy consumption (Swedish Energy Agency, 2008). Harvest regimes have responded to this growing demand for biomass by becoming increasingly mechanized, with preference for whole-tree harvesting (WTH) systems for both thinnings and final clearcut harvests.[4, 8, 50, 32] From 50 to 80 percent of slash is typically removed, depending on site conditions and economic constraints.[32] By some estimates, the share of bioenergy in Sweden could feasibly double before environmental and economic considerations fully constrain this supply.[43]

Sweden is 67 percent forested, and the vast majority of these forests are held by private owners with high willingness to manage their forest and harvest timber. The responsibility for ensuring that energy wood harvests are done in a sustainable manner is largely left to individual landowners, and the greatest area of concern that landowners have about the sustainability of biomass harvesting centers on nutrient cycling and site productivity.[52] WTH clearcutting systems can increase soil nutrient losses by up to 7 percent, lead a reduction in site productivity of up to a 10 percent, and have been linked to an increased rate of loss of biodiversity in managed forests in Sweden.[54, 8, 49] In an attempt to mitigate these risks, the Swedish Forest Agency developed a set of recommendations and good-practice guidelines for WTH in 1986; these were updated in the 1990s and codified in the Swedish Forest Act of 2002. This legislation seeks to control WTH practices in order to limit impacts to forest soils, water resources, and long-term site nutrient balances.

The general approach of Sweden's guidelines and regulations is to classify different sites according to the risks associated with biomass removal at these sites. Different recommendations are then applied based on these classifications. In Sweden these specifications are to ensure that

- all forest residues are dried and needles are left on-site before biomass removal,
- sites in northern Sweden with abundant lichens should be avoided, and
- sites with acidified soils, peat lands, or sites with a high risk of nitrogen depletion should be compensated with ash and nitrogen application.

Like other Nordic countries, Sweden prohibits in-stand drying of forest residues in late spring and early summer to manage risks associated with bark beetle infestations. The guidelines and regulations also specify appropriate forest residue removal rates for different regions of Sweden, based on the risk of soil nutrient loss associated with historic and current patterns of acid deposition in these different regions. WTH clearcut operations are prohibited where they may negatively impact endangered species. The guidelines also stipulate that at least 20 percent of all slash must be left on-site. In addition to these site-specific guidelines, Swedish guidelines and regulations include criteria and indicators for sustainable forest management, forest certification, legislation, soil fertility, soil organic matter, wood production, biodiversity and wildlife, insects and fungi, hydrology and water quality, archaeological resources, cultural resources, recreational resources, nature conservation, silviculture, retention of tree species that are less commonly left in the stand, and stump harvesting.[53]

To hedge against the risk of soil nutrient depletion, the Swedish Forest Agency introduced additional wood ash recycling requirements in 2008; these supplement existing guidance on fertilization. The updated guidelines and regulations require that ash be applied to sites if the amount of harvest residues removed over the course of a rotation exceeds a half ton per hectare (0.2 tons per acre). For areas where biomass removals do not exceed this limit, ash recycling is deemed unnecessary; however, the regulation stipulates that ash be recycled in areas of high acid deposition, such as the southwest portion of the country. In Sweden, typical biomass removals are 0.5–1 ton per hectare, so recycling is de facto required on most sites. The prescription is to apply 2–3 tons per hectare every ten years and not to exceed two applications (i.e., 6 tons of ash per hectare). Ash is also supposed to meet certain chemical composition standards and be hardened when applied to facilitate infiltration of nutrients into soils.[32] Sweden's guidelines also suggest that it is acceptable to apply ash in stands that have not yet been harvested, as a means to mitigate potential loss of site productivity if whole-tree removals are planned. Sweden is a strong proponent of forest certification, and the Swedish FSC standards specify that the recommendations of the Swedish forest agency are to be followed where biomass is used for energy.

5B. Finland

Finland is 74 percent forested with boreal and sub-boreal mixed softwood forests largely dominated by pine, spruce, and birch species. Upwards of 80 percent of the domestic roundwood supply comes from the three-quarters of the land base that is in private ownership.[27] This land base supports a robust bioenergy sector. A full 20 percent of Finland's total energy consumption comes in the form of bioenergy, with 11 percent of the nation's electricity production coming from wood.[25, 27, 50] Approximately 47 percent of the annual Finnish roundwood supply is consumed in the production of energy.[25] Finland also imports an estimated 21 percent of the total wood it consumes for energy.[30] Finnish forest policy has made a goal of increasing the annual use of wood for energy by 5 million cubic meters, or nearly 5 million green tons.[52]

As in Sweden, harvests in Finland are highly mechanized, and WTH clearcuts are common practice. It is estimated that typical harvests of this nature remove between 60 and 80 percent of the total site biomass.[54, 28, 47, 50, 61] Finnish biomass harvesting guidelines suggest that 30 percent of residue should remain and be distributed evenly over the site following clearcuts. In addition to final harvests, biomass is also produced though early and mid-rotation thinning of small-diameter trees. This activity is not widespread across Northern Europe, due to operational and economic constraints, with the exceptions being Denmark, some Baltic states, and Finland.[2, 50] Finland subsidizes both early rotation thinnings and the subsequent production of energy in order to support the production of commercial timber products.[53]

The Finnish approach to ensuring forest sustainability is to classify different sites according to the risks associated with biomass removals from these sites and to then apply different management recommendations based on these classifications. Site classifications include: mesic uplands and sites with fertile soils, sub-xeric and xeric sites, barren upland sites with lichens, peatland forest sites, stands with rocky soils, stands with low levels of available nutrients, water conservation areas, managed stands with more than 75 percent spruce, and stands where biomass removals have previously been performed through WTH clearcutting systems.[53]

Finnish guidelines contain operational protocols for site preparation, stump harvests, storing energy wood at roadside, and management of rotten wood.[3] Additional issues addressed include wood production, biodiversity, wildlife habitat, insects and fungi, recreational resources, silviculture, stump harvesting, and biomass production costs (Stupak et al., 2008). Specific recommendations include that large dead trees either standing or on the ground should not to be collected or damaged. Exceptions can be made for certain salvage harvests in the wake of a significant disturbance event, and protocols for this are explicit. Riparian areas must be left unharvested, and the requisite width of riparian management zones depends on site characteristics (e.g., slope of harvesting sites and other watershed characteristics).

In Finland, it is also common and recommended practice to remove stumps and roots in certain circumstances. This is done mainly in spruce stands as a part of preparing the site for the next planting and as a risk-management practice used to avoid root rot.[27, 52] Stump wood cannot be removed from riparian areas or steep slopes unless "preventative measures" are taken. Stumps are also not to be removed from wetlands, sites with rocky soils, dry soils, or thin soils, or if stumps are less than 6 inches in diameter. Stump removal protocols also recommend leaving a certain target number of stumps per acre for different soil types.[21] Finland prohibits in-stand drying of forest residues in late spring and early summer to manage risks associated with bark beetle infestations.

While Finland does not require ash recycling through regulations, it is estimated that more than 10 percent of wood ash produced is typically returned to forests, usually in peat soils where it acts as a fertilizer. Finnish guidelines recommend that wood ash be spread on peat land after thinnings to act as a fertilizer, or if logging residues or stumps are extracted from nutrient-poor sites.[53] Ash is commonly spread with forwarders at a rate of about 3–5 tons per acre every ten years, i.e, slightly more than is recommended in Sweden.[47, 53]

5c. Denmark

Denmark has less forestland than Finland or Sweden but woody biomass is still an important energy source. The Danish Biomass Agreement of 1993 called for increasing the rate of biomass produced for energy (primarily heating) by 1.4 million tons annually, with woody biomass to contribute 0.2–0.4 million tons annually.[52]

In Denmark, whole-tree chipping of small diameter trees from mid-rotation thinning is common; guidelines for public forestry lands recommend that these materials dry for at least two months before they are chipped, to avoid nutrient losses.[47] It is not common practice to harvest slash associated with final clearcut harvests because of the logistical constraints in removing this biomass and/or because of concerns about soil nutrient depletion and impacts to plant and animal communities.[50] Issues addressed in Danish guidance documents include soil fertility, soil organic matter, management of insects and fungi, silviculture, stump harvesting, and production costs.[52, 53] Danish guidance documents classify sites according to the dominance of hardwoods or softwoods and recommend that "stand-wise evaluations" be completed prior to harvests and that forest residues are dried for at least two months during the spring or summer. Other recommendations focus on stands of special conservation value for flora and fauna, and others for which wood production is not a primary objective. Guidance recommends avoiding exposed forest edges, nature conservation areas, and rare forest types.

Danish forest policy generally suggests that nutrients lost in logging may be compensated for through fertilization, and that stumps are not to be removed.[52, 53] Forest policy also suggests that the maximum allowable amount of wood ash that should be applied over ten years ranges from 0.5 to 7.5 tons per hectare, although this depends on the specific chemical composition of the ash.

5d. The United Kingdom

With the UK's biomass-based energy sector growing, the UK Forestry Commission has released a series of technical reference documents designed to help forest managers assess risks associated with biomass harvests.[41, 59, 57, 58] These documents cover slash removal and stump removal as well as the associated risks to soil fertility, soil organic matter, biodiversity and wildlife, hydrology and water quality, archaeological resources, cultural resources, recreational resources, and nature conservation.

The UK biomass harvesting guidance encourages managers to first classify sites according to their susceptibility to risks associated with biomass removal. In 2009, the UK Forestry Commission reevaluated the existing system of site classification used to assess the acceptability of biomass harvests. The previous classification had restricted the overall biomass supply by classifying large portions of the UK as sensitive forestland. The new classification was implemented to facilitate a more reliable biomass supply without adversely impacting natural resources.[58] The guidance classifies sites according to soil types as being of low, medium, or high risk and lists associated slash and stump removal management actions for each of these soil classifications. The assessment of site suitability for biomass harvests is to be based on the most sensitive soil type that covers greater than 20 percent of the site area. The guidelines suggest that site-specific risk assessments should be carried out before each harvest and should include a soil test. The guidance documents also recognize that there are significant uncertainties about the long-term sustainability of removing these materials and suggests that additional research is required to assess the full range of impacts, including net carbon balance.

Photo: UK Forestry Commission

In the UK, biomass harvests typically occur in conifer plantations where slash is windrowed and left for 3–9 months following final timber harvests. This material is subsequently bailed and collected.[58] Thinnings also supply biomass, but this volume is currently not significant. The guidelines suggest that thinnings pose less of an immediate risk to soil nutrient and base cation balance than do final clearcut harvests. In addition to removing timber harvest residues, there is increased interest in harvesting stumps. The UK Forestry Commission recently released interim guidance on stump removal, which states that in some instances the benefits of stump harvesting will outweigh the potential disadvantages, but that the removal of stumps very much requires a site-by-site evaluation. The report acknowledges that stump removal "poses a number of risks to the forest environment that can threaten both sustainable forest management and the wider environment," including soil compaction, rutting, sedimentation, soil carbon loss, removal of macro- and/or micronutrients, and loss of soil buffer capacity due to loss of base cations.[59]

It is important to note that the slash removal guidance states that residue removals are acceptable on all high risk soil types as long as compensatory applications of fertilizer or wood ash are used. The guidelines in turn warn that application of wood ash may induce either nitrogen deficiency on nutrient-poor soils, or leaching of nitrates and/or soil acidification on nitrogen-saturated sites. The guidelines also point out that the application of fertilizers and wood ash may not be acceptable under forest certification programs that have stringent standards for the application of chemicals.

6. OTHER ORGANIZATIONS AND CERTIFICATION SYSTEMS

6A. International Organizations

A number of international organizations have take up the issue of biomass harvest and retention. The International Energy Agency (IEA) conducts research through several programs. For example, Task 43 (feedstocks to energy markets) considers environmental issues, establishment of sustainability standards, exploration of supply chain logistics, and appropriate connections between harvesting standards and international trade and energy markets (www.ieabioenergy.com). The Global Bioenergy Partnership (GBEP) seeks to develop a common methodological framework to measure greenhouse gas emissions from biofuels and to developing science-based benchmarks and indicators for sustainable biofuel production. Throughout 2009, a GBEP task force was focused on the development of a set of relevant, practical, science-based, voluntary criteria and indicators as well as examples of best practices for biomass production. The criteria and indicators are intended to guide nations as they develop sustainability standards and to facilitate the sustainable development of bioenergy in a manner consistent with multilateral trade obligations (www.globalbioenergy.org). The Ministerial Conference on the Protection (MCPC) of Forests is a pan-European process to identify criteria and indicators for sustainability and adaptive management. In 2007, the MCPC initiated a special project to assess the need for sustainability criteria given the increased demand for biomass. The implications of carbon balances on biomass energy are also being explored and may impact the EU's 2009 Renewable Energy Directive (www.foresteurope.org).

6B. Federal Biomass Policy

U.S. federal policy on the use of woody biomass from forests has focused on how to define biomass and how or if sustainable should be legislated. Key areas of legislative focus are the type of wood that qualifies as renewable biomass, what kinds of ownerships can provide woody biomass, and the types of forest from which woody biomass can be procured. The following summary highlights aspects of federal law and proposed legislation that most directly influence the use of woody biomass from forests for energy.

- **Section 45 of the U.S. Internal Revenue Code** The tax code defines what kinds of biomass are eligible for producing energy that qualifies for federal tax incentives such as the federal renewable energy production tax credit and investment tax credit. "Closed-loop biomass" is defined as "any organic material from a plant which is planted exclusively for purposes of being used at a qualified facility to produce electricity," whereas "Open-loop biomass" includes a number of opportunity fuels, such as "any agricultural livestock waste nutrients," "any solid, nonhazardous, cellulosic waste material or any lignin material which is derived from...mill and harvesting residues, pre-commercial thinnings, slash, and brush," a variety of "solid wood waste materials," and agricultural biomass sources.

- **Farm Security and Rural Investment Act of 2002 Public Law 107–171—May 13, 2002** This law included both "trees grown for energy production" and "wood waste and wood residues" in its definition of biomass.

- **Energy Policy Act of 2005 Public Law 109–58—Aug. 8, 2005** The Energy Policy Act defined biomass to include "any of the following forest-related resources: mill residues, pre-commercial thinnings, slash, and brush, or non-merchantable material," as well as "a plant that is grown exclusively as a fuel for the production of electricity." This definition was more detailed than the previous 2002 Farm Bill and excluded material that would traditionally sell as timber.

- **The Energy Independence and Security Act of 2007 Public Law 110–140—Dec. 19, 2007** The Energy Independence and Security Act included the Renewable Fuels Standard (RFS) and provided the most detailed definition of biomass to date. One of the most important distinctions it made was to separate woody biomass from private and federal lands. Biomass from federal lands was excluded and could not be used to produce renewable fuels. However, an exception was provided for woody biomass removed from the "immediate vicinity of buildings" for fire protection. The RFS also excluded biomass from certain types of forests seen as rare: "ecological communities with a global or state ranking of critically imperiled, imperiled, or rare pursuant to a State Natural Heritage Program, old growth forest, or late successional forest." The RFS made an effort to discourage conversion of native forests to plantations by excluding woody biomass from plantations created after the enactment of the law. The RFS also established a subsidy of up to $20 per green ton of biomass delivered for facilities producing electric energy, heat, or transportation fuels.

- **Food, Conservation, and Energy Act of 2008 Public Law 110–246—June 18, 2008** The 2008 Farm Bill continued the trend toward great specification in the definition of renewable biomass. This time woody biomass from federal lands was included where it was the byproduct of preventive treatments to reduce hazardous fuels, contain disease or insect infestation; or restore ecosystem health. On private lands, the definition included essentially all trees and harvest residues. The exclusion for rare forests in the 2007 RFS was not included. The 2008 Farm Bill also initiated the **Biomass Crop Assistance Program (BCAP)** to improve the economics of establishing and transporting energy crops and collecting and transporting forest biomass. Regarding eligibility requirements for this program, forest lands producing biomass must be covered by a "forest management plan." The determination of what constitutes an "acceptable plan" is at the discretion of the State Forester.

Other legislation has been proposed that includes more specific provisions designed to ensure the sustainability of biomass production. For example, HR 2454 would require that biomass from federal land be "harvested in environmentally sustainable quantities, as determined by the appropriate Federal land manager." S 1733, introduced September 9, 2009, stipulates that biomass be produced while ensuring "the maintenance and enhancement of the quality and productivity of the soil" and promoting the "well-being of animals." The future fate of the federal biomass definition is likely to be part of the large climate-change legislation being debated in Washington. Climate-change legislation may include a national Renewable Energy Standard (i.e., a renewable portfolio standard) that would dictate what kind of woody biomass can be included to meet renewable electricity generation goals. Some proposals would shift the burden of sustainability to the states and require biomass harvesting guidelines or regulations that meet some federal oversight.

6c. Forest Stewardship Council: U.S. National Forest Management Standard


Photo: Zander Evans

The FSC standards for the U.S. do not specifically address biomass or whole tree harvests. In other words, "biomass and whole tree harvests are addressed along with other types of removals."[23] The FSC U.S. National Standard covers biomass harvesting at a more general level than most state guidelines, since they are nationwide. The main sections that affect biomass harvest are Criterion 6.2 (habitat for rare species), 6.3 (ecological functions), and 6.5 (soils and water quality). For example, Indicator 6.3.f of the guidelines requires that "management maintains, enhances, or restores habitat components and associated stand structures, in abundance and distribution that could be expected from naturally occurring processes"; these habitat components include "live trees with decay or declining health, snags, and well-distributed coarse down and dead woody material." This proposed requirement would place some limits on biomass removal, but it is not specific about the amount of DWM that should be retained on-site. Indicator 6.5.c limits multiple rotations of whole tree harvesting to sites where soil productivity will not be harmed.

Since FSC guidelines are not focused solely on biomass harvests, they go beyond other biomass guidelines in areas such as habitat connectivity. By the same token, because FSC guidelines cover many different kinds of harvests in many different forest types with diverse forest management objectives, the standards do not contain many subtopics that are specific to biomass harvest (Appendix I).

The FSC standards are considered "outcome focused." Rather than prescribing how to achieve desired outcomes, they allow a variety of practices to be used, so long as the management objectives and the FSC standards are not compromised. For example, one element that shows up in some biomass guidelines is re-entry, but FSC does not include this. Missouri's guidelines advise, "Do not re-enter a harvested area [for the purposes of biomass harvesting] once the new forest has begun to grow," in order to reduce the risk of compaction, which is a recommendation echoed in the Minnesota and Pennsylvania guidelines. The FSC standards, however, do not specifically advise against re-entering a stand for the purpose of biomass harvesting. Instead, issues of compaction and the impacts of other soil disturbing activities are addressed in relation to all management activities under both 6.5 and 6.3.

6d. Other Voluntary Certification Systems

Other voluntary certification systems have standards which may influence forest biomass harvest and retention. For example, the Council for Sustainable Biomass Production (CSBP) released draft standards in 2009 and plans to release a preliminary standard in 2010.[14] The draft standards were open for stakeholder and expert review and comment. The CSBP standards address soil, biological diversity, water, and climate change. As with FSC standards, CSBP makes general recommendations such as "retain biomass materials required for erosion control and soil fertility" (1.1.S3), but do not provide specific guidance on retention of DWM or snags.

7. COMMON ELEMENTS OF BIOMASS HARVESTING GUIDELINES

Though the existing biomass guidelines cover different ecosystems, they share a number of important elements. The following sections assess the similarities and differences between the guidelines' recommendations on dead wood, wildlife and biodiversity, water quality and riparian zones, soil productivity, and silviculture. In addition, we compare the process used to develop each set of guidelines.

7a. Dead Wood

One of the central concerns in biomass removal is the reduction of the quantity of dead wood on-site. Maine's guidelines recommend leaving tops and branches scattered across the harvest area "where possible and practical." To ensure sufficient DWM debris is left on-site, Michigan's draft guidelines recommend retention of one-sixth to one-third of the residue less than four inches in diameter. Minnesota guidelines recommend leaving all preexisting DWM and to "retain and scatter tops and limbs from 20 percent of trees harvested." Wisconsin's guidelines recommend retaining all pre-harvest DWM and tops and limbs from 10 percent of the trees in the general harvest area, with a goal of at least 5 tons of FWM per acre. Wisconsin's guidelines also point out that "some forests lack woody debris because of past management," and that extra DWM should be left in those areas. Pennsylvania's guidelines suggest leaving 15 to 30 percent of "harvestable biomass" as DWM, while Missouri's suggest 33 percent of harvest residue (with variations for special locations such as stream sides).

Maine, Minnesota, Pennsylvania, and Wisconsin suggest leaving all snags possible. Except for some hazard exceptions, California requires retention of all snags. Missouri provides an example of clear and specific recommendations by suggesting 6 per acre in upland forests and 12 per acre in riparian corridors. Michigan does not have a specific recommendation for snag retention.

7b. Wildlife and Biodiversity

Many of the potential wildlife and biodiversity impacts stem from leaving too little dead wood on-site. The biomass guidelines reviewed here agree on the importance of avoiding sensitive sites for wildlife. These include areas of high biodiversity or high conservation value such as wetlands, caves, and breeding areas. Obviously, areas inhabited by threatened or endangered animals and plants receive special consideration. However, as the Minnesota guidelines point out, biomass harvesting may still be appropriate if management plans include specific strategies for maintaining habitat for rare species and/or to restore degraded ecosystems. Pennsylvania's guidelines suggest that biomass removal may be an opportunity to "develop missing special habitats, such as herbaceous openings for grouse and other species, through planting, cutting, or other manipulations." Additional suggestions from state guidelines include inventorying habitat features on the property, promoting individual trees and species that provide mast, and retaining slash piles that show evidence of use by wildlife. Missouri's guidelines make the case against forest conversion in terms of wildlife: "Do not convert natural forests into tree plantations or pasture; natural forests provide more wildlife food and habitat."

7c. Water Quality and Riparian Zones

Photo: Zander Evans

In general, water quality and riparian concerns do not change with the addition of biomass removals to a harvest plan. Streams and wetlands tend to be protected by existing regulation. For example, Maine's guidelines cite the existing laws governing water quality protection as well as the publication *Protecting Maine's Water Quality*. Where restrictions in wetlands and riparian zones are defined in terms of basal area, more specific guidance may be needed for biomass harvests, which can have a large ecological impact with a small change in basal area. An example of riparian recommendations from Minnesota's guidelines is to "avoid harvest of additional biomass from within riparian management zones over and above the tops and limbs of trees normally removed in a roundwood harvest under existing timber harvesting guidelines." Though the Missouri Watershed Protection Practice already includes requirements for stream and river management zones, the Missouri biomass guidelines reiterate how to protect streams and rivers during a harvest.

7d. Soil Productivity

As with water quality, some aspects of soil productivity are usually included in standard forestry BMPs. For instance, Minnesota's biomass guidelines point readers to the state's timber harvesting guidelines, which contain sections titled "Design Outcomes to Maintain Soil Productivity" and "Minimizing Rutting." However, Minnesota's biomass guidelines do add warnings about harvesting biomass on bog soils and shallow soils (less than 8 inches) over bedrock. An appendix to Wisconsin's guidelines lists over 700 specific soil map units which are nutrient poor and unlikely to be able to support sustainable biomass removal. Maine's guidelines use the Briggs classification of soil drainage classes to identify sites that are more sensitive to biomass removals.9 Missouri's guidelines contain a specific section on sustaining soil productivity, especially on steep slopes and shallow soils. Michigan recommends leaving more than one-third of harvested tops on shallow, nutrient-poor or semi-organic soils. However, Michigan's guidelines suggest that the amount of retention can be reduced on jack pine stands on nutrient poor sites.

Another concern that arises with biomass harvest is removal of the litter layer or forest floor. Maine, Michigan, Minnesota, Pennsylvania, and Wisconsin's guidelines state that forest floor, litter layer, stumps, and root systems should all be left.

7e. Silviculture

Many silvicultural prescriptions call for the removal of small, unhealthy, or poorly formed trees to open up more growing space for crop trees or regeneration, but these types of removals often cost money rather than generate income. By providing income from the removal of this material, biomass markets can help support good silviculture. At the same time, biomass removals raise some silvicultural concerns. The Minnesota guidelines point out that an increase in the amount of live vegetation removed may cause swamping, i.e., a decrease in transpiration and an increase in soil moisture. Swamping can kill seedlings and negatively impact regeneration. Removal of tree tops and branches may also remove seeds or cones, which may reduce the amount of natural regeneration. Biomass removals can help deal with forest insect problems, but removing the biomass material from the site must be timed to avoid contributing to pest problems such as bark beetles.

Some states have used biomass guidelines to make silvicultural recommendations that may improve stands but are not directly related to biomass harvesting. The Missouri biomass guidelines provide silvicultural suggestions for the number of crop trees per acre for stands in different stages of development. Pennsylvania's guidelines suggest that forest stewards "provide for regeneration each time harvests are made under the uneven-aged system," focus on the residual stand more than the trees being removed, and avoid high grading. Wisconsin's guidelines suggest retaining "reserve trees and patches at 5–15 percent crown cover or stand area" in even-aged regeneration cuts and three or more large-cavity trees, large mast trees, and trees that can become large trees in the future. Maine's guidelines recommend retention of cavity and mast trees while Wisconsin's guidelines recommend retaining five percent of the area unharvested in salvage operations following severe disturbances.

Another operational recommendation that Minnesota, Missouri, and Pennsylvania all make is to avoid re-entering a stand to remove biomass. Re-entering a site where timber was recently harvested can increase site impacts such as soil compaction and harm post-harvest regeneration. For this reason, the Missouri guidelines advise that "woody biomass should be harvested at the same time as sawlog timber to avoid re-entry." Maine's guidelines recommend that woody biomass removal be integrated with traditional forest operations where possible.

7f. Biomass Guidelines Development

The process of developing guidelines can be as important as the specific recommendations. Most guidelines try to draw from the most recent forest science. Developing new biomass guidelines allows states to incorporate new research and ideas. Minnesota used funding from the University of Minnesota Initiative for Renewable Energy and the Environment to conduct a review of the scientific literature on biomass harvests. Other guidelines borrow from existing guidelines. For example, Pennsylvania's guidelines borrow extensively from Minnesota's guidelines and summarize the FSC's standards for the region.

The amount of stakeholder participation varies across the guidelines. While Pennsylvania's guidelines were created from within the DCNR, Minnesota, Missouri, and Wisconsin included public participation and a technical committee from the wider forestry community. Public participation can be unwieldy, but often generates greater public support for forestry projects.[20]

Some of the biomass guidelines, such as those from New Brunswick, Canada, focus on the identification of geographies where biomass harvesting is most appropriate. Wisconsin takes a complementary approach, identifying soil types where biomass removal is inappropriate. By mapping soil types, guidelines can highlight those areas where concerns about nutrient depletion are lowest. Suitability mapping also permits the consideration of the landscape-scale impacts of biomass harvesting. Pennsylvania's guidelines are notable because they consider the supply of biomass from forests as well as the appropriate scale of utilization. As mentioned previously, Pennsylvania's guidelines make a case for small-scale (less than 2,000 tons of biomass per year) biomass utilization facilities.

8. CONCLUSION

This revised assessment of biomass guidelines reviews a wide range of approaches to the sustainable use of biomass that can inform the development of guidelines in Massachusetts. The section on New York and New England may be the most helpful, because these states are dealing with similar timber types and land ownership patterns. However, there are number of other state-based approaches, such as those of Minnesota and Michigan, that can be readily transferable. Northern Europe has a long history of intensive biomass use, and while their harvesting systems and approach to forest management are currently very different, their approaches to ecological issues can be translated to concerns in Massachusetts. The sections on other organizations and federal policy provide insight into how Massachusetts guidelines might be influenced or integrated with other approaches.

The final section, which explores the common elements of biomass harvesting guidelines, offers a structure to develop guidelines tailored to Massachusetts. The Forest Guild has used that structure to develop a set of guidelines, *Biomass Retention and Harvesting Guidelines for the Northeast*, which is readily applicable to Massachusetts. These guidelines are included as a separate document.

The following recommendations for the development of future biomass guidelines in Massachusetts are based on the existing guidelines and available science, and will change as more is learned about biomass removals:

- Develop guidelines that are based on sound science and include wide stakeholder engagement. As the Minnesota guidelines describe it, "Provide the best scientific judgment, tempered by the consensus process among a broad group of forest management interests, related to practices that will sustain a high level of biodiversity."
- Define "woody biomass" and other important terms clearly.
- Base biomass harvesting recommendations on local ecology. They should recognize state or local natural communities, disturbance regimes, and other ecological traits. Technical committees and scientific literature provide a firm base for harvest recommendations.
- Consider developing guidelines for each of the subtopics listed in Appendix I—though not all subtopics will be appropriate for every location.
- Make clear and specific recommendations for the retention of standing dead trees, existing CWM, CWM generated by the harvest, FWM, and forest floor and litter layer. Because reduction of dead wood is one of the key differences between biomass removal and traditional harvest, it should be a focus of future guidelines. Nutrients removed from the site should be replenished. For even-aged systems, nutrients should be replenished to adequate levels by the end of the rotation. Uneven-aged systems should maintain nutrient levels close to the optimum. Nutrient levels may be temporarily reduced after each entry, but should return to adequate levels by the next cutting cycle.
- Make biomass guidelines practical and easy to follow. Where biomass guidelines supplement existing forestry rules and guidelines, the new guidelines should provide clear references to the relevant sections of the existing rules and guidelines both for convenience and to increase the likelihood of implementation.
- Take advantage of the opportunity to create new forestry recommendations that encourage excellent forestry: forestry that goes beyond minimum BMPs and enhances the full suite of ecological values. For example, biomass guidelines may be an opportunity to suggest alternatives to high grading and other practices that damage the long-term health of the forest. Similarly, biomass guidelines can present the chance to advocate for appropriately scaled biomass utilization, as Pennsylvania guidelines already do.

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10. REFERENCES

1 Aguilar, F., and H. E. G. Garrett. 2009. Perspectives of Woody Biomass for Energy: Survey of State Foresters, State Energy Biomass Contacts, and National Council of Forestry Association Executives. *Journal of Forestry* 107(6):297-306.

2 Ahtikoskia, A., J. Heikkila, V. Aleniusa, and M. Sirenc. 2008. Economic Viability of Utilizing Biomass Energy from Young Stands-the Case of Finland. *Biomass and Bioenergy* 32:988 - 996.

3 Aijala, O., K. M., and M. Halonen. 2005. Energy Wood Harvest from Clear Cuts, Guidelines. Quality Project of Energy Wood Harvest in Clear Cut. Feric Tapio Guidelines. Finland.

4 Andersson, G., A. Asikainen, R. Björheden, P. W. Hall, J. B. Hudson, R. Jirjis, D. J. Mead, and J. Nurmi. 2002. Production of Forest Energy. Pages Ch. 3. pp. 49-123 in G. F. Weetman, J. Richardson, R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. *Bioenergy from Sustainable Forestry: Guiding Principles and Practice*. Kluwer Academic Publishers, The Netherlands.

5 Arnosti, D., D. Abbas, D. Current, and M. Demchik. 2008. Harvesting Fuel: Cutting Costs and Reducing Forest Fire Hazards through Biomass Harvest. Institute for Agriculture and Trade Policy, Minneapolis, MN.

6 Bauer, J. M., and P. J. Weisberg. 2009. Fire History of a Central Nevada Pinyon-Juniper Woodland. *Canadian Journal of Forest Research* 39(8):1589-1599.

7 Benjamin, J. G. 2010. Considerations and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine. Miscellaneous Publication 761, University of Maine, Maine

Agricultural and Forest Experiment Station, Orono, ME.

8 Berg, S. 2003. Harvesting Technology and Market Forces Affecting the Production of Forest Fuels from Swedish Forestry. *Biomass and Bioenergy* 24(4-5):381-388.

9 Briggs, R. D. 1994. Site Classification Field Guide. Maine Agricultural and Forest Experiment Station, Orono, ME.

10 Brown, J. K., Elizabeth D. Reinhardt, and K. A. Kramer. 2003. Coarse Woody Debris: Managing Benefits and Fire Hazard in the Recovering Forest. RMRS-GTR-105, US Forest Service, Rocky Mountain Research Station, Ogden, UT.

11 California. 2010. California Forest Practice Rules. *in Title 14, California Code of Regulations. Chapters 4, 4.5 and 10. Appendix Technical Rule Addendum # 2, B*.

12 Cassidy, G., J. Aron, and M. Tremblay. 2003. Rhode Island Conservation Management Practices Guide. Rhode Island Forest Conservator's Organization, Scituate, RI.

13 Chapman, C., G. Donovan, S. Fay, C. Foss, G. Jones, B. Leak, D. Merski, F. Mitchell, D. Publicover, M. Seeger, T. V. Ryn, and M. Yamasaki. 1997. Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire. New Hampshire Division of Forests & Lands and Society for the Protection of New Hampshire Forests, Concord, NH.

14 CSBP. 2009. Draft Standard. Council for Sustained Biomass Production, Dillon, CO.

15 CT DEP. 2007. Best Management Practices for Water Quality While Harvesting Forest Products. Connecticut Department of Environmental Protection, Bureau of Natural Resources, Division of Forestry, Hartford, CT.

16 Ellefson, P. V., and A. S. Cheng. 1994. State Forest Practice Programs: Regulation of Private Forestry Comes of Age. *Journal of Forestry* 92:34-37.

17 Ellefson, P. V., M. A. Kilgore, and J. E. Granskog. 2006. State Government Regulation of Forestry Practices Applied to Nonfederal Forests: Extent and Intensity of Agency Involvement. *Journal of Forestry* 104:401-406.

18 Elliot, C., editor. 2008. Biodiversity in the Forests of Maine: Guidelines for Land Management. University of Maine Cooperative Extension. Bulletin 7174, Orono, ME.

19 Evans, A. M., and A. J. Finkral. 2009. From Renewable Energy to Fire Risk Reduction: A Synthesis of Biomass Harvesting and Utilization Case Studies in Us Forests. *Global Change Biology Bioenergy* 1(3):211-219.

20 Evans, A. M., and G. McKinley. 2007. An Evaluation of Fuel Reduction Projects and the Healthy Forests Initiative. Forest Guild, Santa Fe, NM.

21 Fernholz, K., S. Bratkovich, J. Bowyer, and A. Lindburg. 2009. Energy from Woody Biomass: A Review of Harvesting Guidelines and a Discussion of Related Challenges. Dovetail Partners, Inc., Minneapolis, MN.

22 Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. Biodiversity in the Forests of Maine: Guidelines for Land Management. University of Maine, Cooperative Extension, Orono, ME.

23 FSC. 2009. Us Forest Management Standard Draft 8.1. Forest Stewardship Council, Washington, DC.

24 Hagan, J. M., and A. A. Whitman. 2006. Biodiversity Indicators for Sustainable Forestry: Simplifying Complexity. *Journal of Forestry* 104(4):203-210.

25 Hakkila, P. 2006. Factors Driving the Development of Forest Energy in Finland. *Biomass and Bioenergy* 30:281-288.

26 Herrick, S., J. Kovach, E. Padley, C. Wagner, and D. Zastrow. 2009. Wisconsin's Forestland Woody Biomass Harvesting Guidelines. PUB-FR-435-2009, WI DNR Division of Forestry and Wisconsin Council on Forestry, Madison, WI.

27 International Energy Agency. 2007. Bioenergy Report Finland. Paris, France.

28 Jacobson, G. L., Jr. 2000. Post-Glacial Changes in Vegetation and Climate in Northern New England. Rhodora 102(911):246-247.

29 Janowiak, M. K., and C. R. Webster. 2010. Promoting Ecological Sustainability in Woody Biomass Harvesting. *Journal of Forestry* 108:16-23.

30 Junginger, M., T. Bolkesj, D. Bradley, P. Dolzan, A. Faaij, J. Heinimo, B. Hektor, O. Leistad, E. Ling, M. Perry, E. Piacente, F. Rosillo-Calle, Y. Ryckmans, P. P. Schouwenberg, B. Solberg, E. Trømborg, A. D. S. Walter, and M. D. Wit. 2008. Developments in International Bioenergy Trade. *Biomass and Bioenergy* 32:717-729.

31 Lattimore, B., C. T. Smith, B. D. Titus, I. Stupak, and G. Egnell. 2009. Environmental Factors in Woodfuel Production: Opportunities, Risks, and Criteria and Indicators for Sustainable Practices. *Biomass and Bioenergy* 33(10):1321-1342.

32 Levin, R., and H. Eriksson. 2010. Good-Practice Guidelines for Whole-Tree Harvesting in Sweden: Moving Science into Policy. *Forestry Chronicle* 86(1):51-56.

33 Mallory, E. C. 2008. Collation of on-Going Canadian Research on Biomass Harvesting and Biodiversity. *in Proceeding of The Scientific Foundation for Sustainable Forest Biomass Harvsting Guidelines and Policies*. Sustainable Forest Management Network, Edmonton, AB.

34 MDC. 2008. Missouri Woody Biomass Harvesting Best Management Practices Manual. Missouri Department of Conservation, Jefferson City, MO.

35 MDNR. 2007. Sustainable Soil and Water Quality Practices on Forest Land. Michigan Department Of Natural Resources, Michigan Department Of Environmental Quality,, Lansing, MI.

36 MDNR. 2009. Michigan Woody Biomass Harvesting Guidance *Draft*. Michigan Department of Natural Resources, Forest, Mineral and Fire Management, Lansing, MI.

37 MFRC. 2007. Biomass Harvest Guidelines. Minnesota Forest Resources Council, St. Paul, MN.

38 MFS. 2004. Best Management Practices for Forestry: Protecting Maine's Water Quality. Maine Department of Conservation's Maine Forest Service, August, ME.

39 MFS. 2008. Maine Forestry Best Management Practices Use and Effectiveness 2006 - 2007. Maine Forest Service, Augusta, ME.

40 MFS, U of ME, and TCNF. 2008. Biomass Retention Guidelines for Timber Harvesting in Maine. Version 4. Maine Forest Service, University of Maine, and the Trust to Conserve Northeast Forestlands, Orono, ME.

41 Moffat, A., B. M. Jones, and B. Mason. 2006. Managing Brash on Conifer Clearfell Sites. Practice Note, UK Forestry Commission, Farnham, England.

42 New Brunswick DNR. 2008. Forest Biomass Harvesting. New Brunswick Department of Natural Resources, Fredericton, New Brunswick.

43 Nilsson, L. J., B. Johansson, K. Astrand, K. Ericsson, P. Svenningsson, and P. Borjesson. 2004. Seeing the Wood for the Trees: 25 Years of Renewable Energy Policy in Sweden. *Energy for Sustainable Development* 8(1).

44 Norton, G., S. Abraham, and A. Veneman. 2003. Memorandum of Understanding on Policy Principles for Woody Biomass Utilization for Restoration and Fuel Treatments on Forests, Woodlands, and Rangelands. U.S. Forest Service and Bureau of Land Management, Washington, DC.

45 NYSF. 2007. Best Management Practices for Water Quality. New York State Forestry, Albany, NY.

46 PA DCNR. 2008. Guidance on Harvesting Woody Biomass for Energy. Pennsylvania Department of Conservation and Natural Resources, Harrisburg, PA.

47 Raison, R. J., P. Hakkila, D. G. Neary, J. A. Burger, P. Angelstam, G. Mikusinski, and M. Breuss. 2002. Effects of Very Intensive Forest Biomass Harvesting on Short and Long Term Site Productivity. in J. Richardson, R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. *Bioenergy from Sustainable Forestry: Guiding Principles and Practice*. Kluwer Academic Publishers, Hingham, MA.

48 Ralevic, P., J. Karau, T. Smith, and J. Richardson. 2008. Iea Bioenergy Task 31 Country Report: Canada. International Energy Agency, Ottawa, Canada.

49 Raulund-Rasmussen, K., I. Stupak, N. Clarke, I. Callesen, H.-S. Helmisaari, E. Karltun, and I. Varnagiryte-Kabasinskiene. 2008. Effects of Very Intensive Forest Biomass Harvesting on Short and Long Term Site Productivity. Pages 29-78 in D. Röser, A. Asikainen, K. Raulund-Rasmussen, and I. Stupak, editors. *Sustainable Use of Forest Biomass for Energy. Springer Netherlands*.

50 Röser, D., A. Asikainen, K. Raulund-Rasmussen, and I. Stupak, editors. 2008. *Sustainable Use of Forest Biomass for Energy—a Synthesis with Focus on the Baltic and Nordic Region*. Springer.

51 Shepard, J. P. 2006. Water Quality Protection in Bioenergy Production: The Us System of Forestry Best Management Practices. *Biomass and Bioenergy* 30(4):378–384.

52 Stupak, I., A. Asikainen, M. Jonsell, E. Karltun, A. Lunnan, D. Mizaraite, K. Pasanen, H. P. rn, K. Raulund-Rasmussen, D. R. ser, M. Schroeder, I. Varnagiryte, L. Vilkriste, I. Callesen, N. Clarke, T. Gaitnieks, M. Ingerslev, M. Mandre, R. Ozolincius, A. Saarsalmi, K. Armolaitis, H.-S. Helmisaari, A. Indriksons, L. Kairiukstis, K. Katzensteiner, M. Kukkola, K. Ots, H. P. Ravn, and P. Tamminen. 2007. Sustainable Utilisation of Forest Biomass for Energy—Possibilities and Problems: Policy, Legislation, Certification, and Recommendations and Guidelines in the Nordic, Baltic, and Other European Countries. *Biomass and Bioenergy* 31:666–684.

53 Stupak, I., T. Nordfjell, and P. Gundersen. 2008. Comparing Biomass and Nutrient Removals of Stems and Fresh and Predried Whole Trees in Thinnings in Two Norway Spruce Experiments. *Canadian Journal of Forest Research* 38(10):2660–2673.

54 Sverdrup, H., and K. Rosen. 1998. Long-Term Base Cation Mass Balances for Swedish Forests and the Concept of Sustainability. Forest Ecology and Management 110(1-3):221-236.

55 Titus, B. D., S. M. Berch, D. M. Morris, R. L. Fleming, P. W. Hazlett, D. Pare, and P. A. Arp. 2008. Synopsis of on-Going Canadian Research on Biomass Harvesting and Site Productivity. *in Proceeding of The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policies.* Sustainable Forest Management Network, Edmonton, AB.

56 Titus, B. D., C. T. Smith, D. Puddister, J. R. Richardson, and C. Young. 2008. Notes from Facilitated Discussions. *in Proceeding of The Scientific Foundation for Sustainable Forest Biomass Harvsting Guidelines and Policies*. Sustainable Forest Management Network, Edmonton, AB.

57 UK Forestry Commission. 2009. *Forests and Soils Guidelines Consultation Draft, July 2009.* Forest Research, the Research Agency of the UK Forestry Commission. http://www.forestry.gov.uk/pdf/FCGL008consultation.pdf/$FILE/FCGL008consultation.pdf

58 UK Forestry Commission. 2009. *Guidance on Site Selection for Brash Removal*. Forest Research, the Research Agency of the UK Forestry Commission. http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/BEST%20PRACTICE/BRASH_RESIDUE_PROTOCOL-1.PDF

59 UK Forestry Commission. 2009. *Stump Harvesting: Interim Guidance on Site Selection and Good Practice*. Forest Research, the Research Agency of the UK Forestry Commission. http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/BEST%20PRACTICE/FC_STUMP_HARVESTING_GUIDANCE_APRIL09.PDF

60 VT DFPR. 1987. Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont. Department of Forests, Parks, and Recreation, Waterbury, VT.

61 Walmsley, J. D., D. L. Jones, B. Reynolds, M. H. Price, and J. R. Healey. 2009. Whole Tree Harvesting Can Reduce Second Rotation Forest Productivity. *Forest Ecology and Management* 257(3):1104-1111.

62 Woodall, C. W., and V. J. Monleon. 2008. Sampling Protocol, Estimation, and Analysis Procedures for the Down Woody Materials Indicator of the Fia Program. NRS-GTR-22, U.S. Forest Service, Newtown Square, PA.

11. APPENDIX I

SUMMARY TABLE OF BIOMASS GUIDELINES

	ME	MN	MO	PA	WI	FSC
Dead Wood						
Coarse woody material	√	√	√	√	√	√
Fine woody material	√	√	√	√	√	√
Snags	√	√	√	√	√	√
Wildlife and Biodiversity				√		
Wildlife	√	√	√	√	√	√
Sensitive wildlife species	√	√	√	√	√	√
Biodiversity	√	√	√	√	√	√
Plants of special concern	√	√	√	√	√	√
Sensitive areas	√	√	√	√	√	√
Water Quality and Riparian Zones						
Water quality	√	√	√	√	√	√
Riparian zones	√	√	√	√	√	√
Non-point source pollution	√	√	√	√	√	√
Erosion	√	√	√	√	√	√
Wetlands	√	√	√	√	√	√
Soil Productivity						
Chemical (Nutrients)	√	√	√	√	√	√
Physical (Compaction)	√	√	√	√	√	√
Biological (Removal of litter)	√	√		√	√	
Silviculture						
Planning	√	√	√	√		√
Regeneration		√		√	√	√
Residual stands	√	√	√	√	√	√
Aesthetics			√	√	√	√
Post operations	√	√	√	√	√	
Re-entry		√	√	√		
Roads and skid trail layout	√	√	√	√	√	√
Disturbance						
Insects		√	√	√	√	√
Disease			√	√	√	√
Fire		√	√	√		√
Fuel reduction		√		√		√
Pesticides		√		√		
Invasives		√	√	√		
Conversion from forest			√	√		√

12. APPENDIX II

LINKS TO BIOMASS HARVESTING GUIDELINES

- Considerations and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine http://www.maine.gov/doc/mfs/pubs/biomass_retention_guidelines.html

- Minnesota: Biomass Harvesting Guidelines for Forestlands http://www.frc.state.mn.us/FMgdline/BHGC.html

- Missouri: Best Management Practices for Harvesting Woody Biomass http://mdc4.mdc.mo.gov/applications/MDCLibrary/MDCLibrary2.aspx?NodeID=2055

- Pennsylvania: Guidance on Harvesting Woody Biomass for Energy http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf

- Wisconsin Council on Forestry: Use of Woody Biomass http://council.wisconsinforestry.org/biomass/

- Forest Stewardship Council http://www.fscus.org/standards_criteria/

- Canada: The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policies http://www.sfmnetwork.ca/html/biomass_workshop_e.html

- New Brunswick: Forest Biomass Harvesting Policy http://www.gnb.ca/0078/Policies/FMB0192008E.pdf

APPENDIX 4–C

FOREST BIOMASS RETENTION AND HARVESTING GUIDELINES FOR THE NORTHEAST

TABLE OF CONTENTS

1. INTRODUCTION AND BACKGROUND

Interest in removing wood with a historically low economic value from forests has increased because of rising fossil fuel costs, concerns about carbon emissions from fossil fuels, and the risk of catastrophic wildfires. Even as federal, state and regional programs encourage the utilization of forest biomass, there are concerns about its potential adverse effects on biodiversity, soil productivity, wildlife habitat, water quality, and carbon storage. At the same time, biomass removal and utilization have the potential to provide a renewable energy source, promote the growth of higher-value trees and forest products, reduce forest fire risk, support the removal of invasive species, and help to meet the economic development goals of rural communities. These guidelines are designed to encourage protection of soils, wildlife habitat, water, and other forest attributes when biomass or other forest products are harvested in the Northeastern United States.

> **Our Principles**
>
> **1. The well-being of human society is dependent on responsible forest management that places the highest priority on the maintenance and enhancement of the entire forest ecosystem.**
>
> **2. The natural forest provides a model for sustainable resource management; therefore, responsible forest management imitates nature's dynamic processes and minimizes impacts when harvesting trees and other products.**
>
> **3. The forest has value in its own right, independent of human intentions and needs.**
>
> **4. Human knowledge of forest ecosystems is limited. Responsible management that sustains the forest requires a humble approach and continuous learning.**
>
> **5. The practice of forestry must be grounded in field observation and experience as well as in the biological sciences. This practical knowledge should be developed and shared with both traditional and non-traditional educational institutions and programs.**
>
> **6. A forester's or natural resource professional's first duty is to the forest and its future. When the management directives of clients or supervisors conflict with the Mission and Principles of the Guild, and cannot be modified through dialogue and education, a forester or natural resource professional should disassociate**

THE FOREST GUILD GUIDELINES

The Forest Guild guidelines are designed to augment and enhance existing Best Management Practices (BMPs) or new state-based biomass guidelines that may, in some cases, leave managers and policy makers looking for more detailed recommendations. While these guidelines were developed to address biomass harvesting, they also are intended to inform all harvests in northeastern forests. We developed these guidelines to assist several audiences: field foresters, loggers, state-based policy makers charged with developing biomass guidelines and standards, biomass facilities wishing to assure sustainability, third party certifiers, and members of the public interested sustainable forest management.

These guidelines are based on the Forest Guild's principles (see text box). Forest Guild members are concerned with reconciling biomass removals with the principles of excellent forestry—forestry that is ecologically, economically, and socially responsible. Excellent forestry exceeds minimum best management practices and places the long-term viability of the forest above all other considerations. It uses nature as a model and embraces the forest's many values and dynamic processes. Excellent forestry maintains the functions, structures, and composition that support the health of the entire forest ecosystem. Excellent forestry is different in each ecoregion, but is guided by science, place-based experience, and continuous learning.

Forest Guild members acknowledge their social responsibilities as forest stewards to address climate change and mitigate the buildup of atmospheric carbon. In addition, we understand how renewable fuels derived from well-managed forests can provide energy security and enhance rural communities. At the same time, we have an ecological imperative to ensure that all our harvests—including biomass harvests—maintain or enhance the ecological values of the forest.

Creating the Guidelines

Our working group consisted of 23 Forest Guild members representing public and private field foresters and resource managers, academic researchers and members of major regional and national environmental organizations. The process was led by Forest Guild staff and was supported by two Forest Guild reports: *Ecology of Dead Wood in the Northeast 4 and An Assessment of Biomass Harvesting Guidelines*.5 Wherever possible we base our recommendations on peer-reviewed science. However, in many cases research is inadequate to connect practices, stand level outcomes, and ecological goals. Where the science remains inconclusive, we rely on field observation and professional experience. The guidelines provide both general guidance and specific targets that can be measured and monitored. These guidelines should be revisited frequently, perhaps on a three-year cycle, and altered as new scientific information and results of field implementation of the guidelines become available.

"Sustainability" and Biomass Harvesting

Using a common definition, sustainable biomass harvests would "meet the needs of the present without compromising the ability of future generations to meet their needs" (Brundtland Commission 1987). Crafting a more precise definition of sustainable forest management is inherently complex because forest ecosystems are simultaneously intricate, dynamic, and variable. Sustainable forest management must integrate elements of ecology, economics, and societal well being. These guidelines primarily pertain to issues of sustaining ecological function and productivity; they are not meant to replace a comprehensive assessment of forest sustainability.

In general, the sustainability of managed forests must be judged on timelines that span generations. Individual trees can persist for centuries and management decisions made today will have important implications well beyond the tenure of any one manger. The indigenous focus on the impact of decisions seven generations into the future is more appropriate. Similarly, sustainability must be judged on scales larger than that of the individual forest stand. For example, large mammal home ranges, water quality, and a viable forestry industry all depend on landscapes that encompass multiple stands. Due to the difficulties of defining appropriate time frames and spatial scales, the concept of forest sustainability is best thought of as an adaptive process that requires regular monitoring and recalibration. Consequently, these guidelines are presented not as static targets to be maintained at all times in all places, but rather as guideposts on a path to sustainability.

Definitions

Biomass

In a scientific context, the term "biomass" includes all living or dead organic matter. In common parlance, biomass usually refers to woody material that has historically had a low value and was not considered merchantable in traditional markets. Biomass harvesting can also involve the removal of dead trees, downed logs, brush, and stumps, in addition to tops and limbs. Changing markets and regional variations determine which trees are considered sawtimber or pulpwood material and which are relegated to the biomass category. This report does not discuss biomass from agricultural lands and short-rotation woody biomass plantations.

In this report, the term biomass refers to *vegetation removed from the forest, usually logging slash, small-diameter trees, tops, limbs, or trees not considered merchantable in traditional markets*. Similarly we use the phrase **biomass harvesting** to refer to the *removal of logging slash, small-diameter trees, tops, or limbs*.

Biomass can be removed in a number of ways. Some harvests remove only woody biomass, some combine the harvest of sawtimber or other products with biomass removal, and some remove biomass after other products have been removed. This report focuses on post-harvest forest conditions and not on the type of harvest. The goal is to ensure the forest can support wildlife, maintain biodiversity, provide clean water, sequester carbon, protect forest soil productivity, and continue to produce income after a biomass harvest or repeated harvests. In some regions, current wood utilization is such that very little woody material is available for new markets such as energy. For these high-utilization areas, application of these guidelines may result in more biomass being left in the forest.

Downed Woody Material

Woody material is sometimes divided into coarse woody material (CWM) and fine woody material (FWM). CWM has been defined as more than 6 inches in diameter at the large end and FWM that is less than 6 inches in diameter at the large end.17 The USDA Forest Service defines CWM as downed dead wood with a small-end diameter of at least 3 inches and a length of at least 3 feet, and FWM as having a diameter of less than 3 inches.25 FWM has a higher concentration of nutrients than CWM. Large downed woody material, such as logs greater than 12 inches in diameter, is particularly important for wildlife. In this report, we use the term **downed woody material (DWM)** to encompass all three of these size classes, but in some circumstances we discuss a specific size of material where the piece size is particularly important.

2. GUIDELINES FOR BIOMASS RETENTION AND HARVESTING FOR ALL FOREST TYPES

The following recommendations are applicable across a range of forest types in the Northeast. However, different forest types naturally develop different densities of snags, DWM, and large downed logs. Unfortunately, even after an exhaustive review of the current science there is too much uncertainty to provide specific targets for each forest type. The recommendations in this section set minimum retention targets necessary for adequate wildlife habitat and to maintain the integrity of ecological process such as soil nutrient cycling. Wherever possible, exceed the targets as a buffer against the limitations of current research. Section 3 presents research that may help landowners and foresters interested in additional tree, snag, and DWM retention tailored to specific forest types.

Site Considerations to Protect Rare Forests and Species

- Biomass harvests in critically imperiled or imperiled forest types (i.e., globally recognized or listed as S1 or S2 in a State National Heritage Program) should be avoided unless necessary to perpetuate the type. Management of these and other rare forest types (for example, those ranked S3 by state Natural Heritage Programs) should be based on guidance from the local Natural Heritage Program and/or other local ecological experts.
- Biomass harvesting may be appropriate in sensitive sites to control invasive species, enhance critical habitat, or reduce wildfire risk. However, restoration activity should be guided by ecological goals and not designed solely to supply biomass. It is unlikely that restored sites will contribute to the long-term wood supply, because biomass removals for restoration may not be repeated at regular intervals.
- Old growth forest stands with little or no evidence of harvesting are so rare in the Northeast that they should be protected from harvesting, unless necessary to maintain their structure or ecological function. Areas with scattered old growth trees or late-successional forest characteristics should be carefully managed to ensure retention of their ecological functions. Biomass generally should not be removed from these areas.

Retention of Downed Woody Material

Though CWM represents a large pool of nutrients in some ecosystems, it likely plays a relatively small role in nutrient cycling for managed Northeastern forests. A review of scientific literature suggests that biomass harvesting is unlikely to cause nutrient problems when both sensitive sites (including low-nutrient sites) and clearcutting with whole-tree removal are avoided (see Evans and Kelty 2010 for a more detailed discussion of the relevant scientific literature). However, there is no scientific consensus on this point because of the limited range of treatments and experimental sites.

Maintenance of Soil Fertility

Biomass harvesting on low-nutrient sites is a particular concern. For example, Hallett and Hornbeck note that "red oak and white pine forests growing on sandy outwash sites are susceptible to nutrient losses due to inherently low-nutrient capitals and/or nutrient depletion by past activities such as farming, fire, and intensive harvesting."9 Maine's *Woody Biomass Retention Guidelines*1 list shallow-to-bedrock soils, coarse sandy soils, poorly drained soils, steep slopes, and other erosion-prone sites as sensitive to biomass removals. We encourage states to identify low-nutrient soil series where biomass harvesting should not occur and those soil series where biomass harvests require particular caution. Wisconsin's *Forestland Woody Biomass Harvesting Guidelines* is an excellent example.11

In areas that do not qualify as low-nutrient sites, where 1/3 of the basal area is being removed on a 15- to 20-year cutting cycle, it is our professional judgment that retaining 1/4 to 1/3 of tops and limbs will limit the risk of nutrient depletion and other negative impacts in most forest and soil types. Additional retention of tops and limbs may be necessary when harvests remove more trees or harvests are more frequent. Similarly where the nutrient capital is deficient or the nutrient status is unknown, increased retention of tops, branches, needles, and leaves is recommended. Conversely, if harvests remove a lower percentage of basal area, entries are less frequent, or the site is nutrient-rich, then fewer tops and limbs need to be retained on-site.

Guidelines for DWM Retention

- In general, when 1/3 of the basal area is being removed on a 15 to 20 year cycle, retain 1/4 to 1/3 of the slash, tops, and limbs from harvest (i.e., DWM).
- Three main factors influence the percentage of tops and limbs that should be left onsite:
  - number of live trees left on-site,
  - time between harvests, and
  - available soil nutrients.
- As harvesting intensity increases (and the three preceding factors decrease) more slash, tops, and limbs from harvests should be left on-site
- As harvesting intensity decreases (and the three factors increase) less slash, tops, and limbs from harvests are required to protect site productivity.
- Avoid harvesting on low-nutrient sites or adjust retention of tops, branches, needles, and leaves.
- Retain DWM of all sizes on-site including FWM, CWM and large downed logs.
- In general, leave DWM distributed across the harvest site. However, there may be cases where piles of DWM provide habitat, or redistribution of DWM collected at the landing would cause excessive damage to soil or regeneration.
- Minimize the removal of needles and/or leaves by harvesting in winter, retaining FWM on-site, or leaving felled trees on-site to allow for needle dro

Retention of Forest Structures for Wildlife and Biodiversity

- Leave and protect litter, forest floor, roots, stumps, and large downed woody material.
- Leave and protect live cavity trees, den trees, other live decaying trees, and snags (i.e., dead standing trees >10"). Individual

snags that must be felled for safety requirements should not be removed from the forest.

Table 1. General Guidelines for Retaining Forest Structures

Structure	Minimum Target (per acre)		Considerations
	Number	Basal area (ft²)	
Live decaying Trees 12 –18 inches DBH	4	3–7	Where suitable trees for retention in these size classes are not present or may not reach these targets due to species or site conditions, leave the largest trees possible that will contribute toward these targets.
Live decaying trees >18 inches DBH	1	2	
Snags >10 inches DBH	5	3	Worker safety is top priority. Retain as many standing snags as possible, but if individual snags must be felled for safety reasons, leave them in the forest.

Table 1 is based on the scientific literature review in *The Ecology of Dead Wood in the Northeast*4 as well as other biomass harvesting and retention guidelines[5]. These guidelines are not meant to be attained on every acre, at all times. Rather, they are average targets to be applied across a stand, harvest block, or potentially an ownership.

- If these forest structures do not currently exist, select and identify live trees to become these structures in the future. Retaining live decaying trees helps ensure sufficient snags in the future. Similarly, both decaying trees and snags can eventually become large downed logs.
- If forest disturbances such as hurricanes, ice storms, and insect infestations create large areas of dead trees, leaving all snags or decaying trees may be impractical. If an area is salvage logged, leaving un-salvaged patches totaling 5% to 15% of the area will provide biological legacies important to wildlife. However, the potential for insect populations to build up in dead trees may prohibit retention of unsalvaged patches in some situations.
- Since there are differences in decay rates and wildlife utilization, retain a variety of tree species as snags, DWM, and large downed logs.
- In areas under even-aged management, leave an uncut patch within or adjacent to every 10 acres of regeneration harvest. Uncut patches, including riparian buffers or other set-asides within the management unit, should total 5% to 15% of the harvest area.
- Build retention patches around large legacy trees, den or cavity trees, large snags, and large downed logs, to maximize structural and habitat diversity.
- Marking retention trees will help ensure that sufficient numbers are retained during the current harvest, and that and they will not be removed in subsequent harvests.
- Management that maintains multiple vegetation layers, from the overstory canopy to the midstory, shrub, and ground layers will benefit wildlife and plant species diversity.

Water Quality and Riparian Zones

In general, water quality and riparian concerns do not change with the addition of biomass removals to a harvest plan. Refer to state water quality best management practices (BMPs) and habitat management guidelines for additional measures to protect streams, vernal pools, and other water bodies (see Appendix I for a list of these BMPs and habitat management guidelines).

- DWM retention described above is also important for water quality, because DWM reduces overland flow and holds water.
- Leave and protect existing woody material in streams, ponds, and lakes. DWM in riparian systems provides sites for vegetation colonization, forest island growth and coalescence, and forest floodplain development.
- Leave and protect live decaying trees (e.g., cavity/den trees), snags, and large downed logs in riparian or stream management zones.
- Keep vernal pools free of slash, tops, branches, and sediment from forestry operations. If slash falls into the pool during the breeding season, it is best to leave it in place to avoid disturbing egg masses or other breeding activity that may already be occurring.
- Within 100 feet of the edge of a vernal pool, maintain a shaded forest floor to provide deep litter and woody debris around the pool. Also avoid ruts, bare soil, or sources of sediment near vernal pools.
- Extra care should be taken working in or around forested wetlands because of their importance for wildlife and ecosystem function. Wetlands are often low-fertility sites and may support rare natural communities, so removal of DWM may be inappropriate.

Harvesting and Operations

Most concerns about the operational aspects of biomass harvesting are very similar to all forestry operations. However, some key points are worth emphasizing:

- Protect forest land from conversion to non-forest use and native forest from conversion to plantations.
- Involve a professional forester (or a licensed forester in states where available) in development of a long-term management plan and supervision of harvests.
- Engage a certified logger from the Master Logger Certification Program or other similar program when harvesting.
- Follow all best management practices (BMPs) for the state or region.
- Plan and construct roads and skid trails based on professional advice and BMPs.
- Integrate biomass harvesting with other forest operations. Re-entering a site where timber was recently harvested to remove

biomass can increase site impacts such as soil compaction and may harm post-harvest regeneration.

- Use low impact logging techniques such as directional felling or use of slash to protect soil from rutting and compaction from harvest machines.
- Use appropriate equipment matched to site and operations.

3. RELEVANT RESEARCH FOR NORTHEASTERN FOREST TYPES

Although there is too much scientific uncertainty to provide specific targets for each forest type, the research described below may help landowners and foresters interested in additional tree, snag, and DWM retention tailored to specific forest types. We hope the need to better quantify decaying tree, snag, and DWM retention requirements will catalyze new research efforts and the retention target can be updated based on new science.

Measurements of Downed Woody Material

Most of the scientific research measures DWM in terms of dry tons per acre rather than percentage of DWM retained after harvest. Tons per acre may not currently be a useful measurement unit for forester and loggers, but we present data in those units here because of their prevalence in scientific literature. This measurement unit may become more prevalent as biomass harvesting increases. Field practitioners typically have not paid a great deal attention to volumes of DWM. Measurement techniques are available to integrate DWM sampling into forest inventories; over time, field practitioners will develop an awareness of volumes-per-acre of DWM, similar to standing timber volumes. The Natural Fuels Photo Series illustrates various levels of DWM and can be used to assist this process (http://depts.washington.edu/nwfire/dps/).

In general, stands have the most DWM when they are young (and trees are rapidly dying from competition) or when they are old (and trees are in various states of decline). Healthy, intermediate-aged stands tend to have less DWM. The following table represents a target range for the mass of DWM left on-site after harvest (including both existing and harvest-generated DWM). The table is based on a number of studies that documented the ranges of observed DWM in managed and unmanaged stands in the Northeast (see Evans and Kelty 2010 for more details). The selected target ranges reflect measurements from unmanaged stands more than those from managed stands and take into account patterns of DWM accumulation during stand development.

Table 2. DWM Ranges by Forest Type

	Northern HW	Spruce-Fir	Oak-Hickory	White and Red Pine
Tons of DWM per acre*	8–16	5–20	6–18	2–50

** Includes existing DWM and additional material left during harvesting to meet this target measured in dry tons per acre.*

Spruce–Fir Forests

Research data on DWM in Maine's spruce-fir forest include 3.4 tons per acre10 and a range from 22 to 117 tons per acre.[20] The low estimate of 3.4 tons per acre is from a survey that includes intensively-managed lands that may not have enough DWM to maintain ecosystem processes and retain soil nutrients,10 while the higher estimates come from unmanaged lands.[20]

The basal area of dead trees from a survey of paper birch-red spruce-balsam fir and red spruce-balsam fir stands ranged from 11 to 43 percent of stand basal area.[23] The Canadian province of Newfoundland and Labrador requires retention of 4 snags per acre, while Maine recommends retaining 3 snags and/or cavity trees greater than 14 inches DBH and one greater than 24 inches DBH.[6, 19] Smith and colleagues recommend retention and recruitment of white birch snags to ensure sufficient snag and DWM density.19 Other guidelines recommend between 5 and 6 snags per acre greater than 8 inches DBH and an additional 4 to 6 potential cavity trees at least 10 inches DBH.[26]

Northern Hardwood Forests

Measures of the DWM in northern hardwood forests are as low as 3.1 tons per acre (Roskoski 1977), but 16 other measurements from 6 scientific articles average 17 tons per acre, with a low of 8 tons per acre.[18, 21, 8, 14, 16, 2] Dead trees made up 3 to 14 percent of the basal area in five hemlock-yellow birch stands and 5 to 34 percent of basal area in sugar maple-beech-yellow birch stands.[23] Other research suggests retention of between 5 and 17 snags per acre.[7, 15, 13] Tubbs and colleagues recommend leaving between one and ten live decaying trees per acre at least 18 inches DBH.[24] Research has documented a range of 7 to 25 to cavity trees per acre in unmanaged stands.[7, 13]

Transitional Hardwood /Oak-Hickory Forests

Measures of the DWM in transitional hardwood forests, i.e., oak-hickory forests of southern New England, range from 5.8 to 18 tons per acre.22, 12 Out of seven oak stands in Connecticut, the number of dead trees ranged from 19 to 44 per ac or 5 to15 percent of basal area.[23]

White and Red Pine Forests

Estimates of the volume of downed dead wood in white and red pine forests range from 1.6 to 50 tons per acre of DWM.3, 10 Unmanaged red pine stands in the Great Lakes area had 30 snags per acre while a managed forest had 6.9 per acre.[3] Many of the red oak and white pine stands on sandy outwash sites are susceptible to nutrient losses because of a combination of low-nutrient capital and past nutrient depletion.[9]

4. CARBON CONSIDERATIONS AND GUIDELINES

To date, forestry or biomass harvesting BMPs have not included guidelines for the management of carbon. However, climate change has the potential to fundamentally change both forests and forestry over the next century. Moreover, climate change has added carbon management to the responsibilities of forest managers and landowners (Forest Guild Carbon Policy Statement 2010). Protecting forests from conversion to other land uses is the most important forest management measure to store carbon and mitigate climate change. Biomass harvests may reduce the incentive to convert forests to other uses by providing additional income to forest landowners, and maintaining the forest industry and availability of markets.

The extent to which forest biomass can serve as a low-carbon alternative to fossil fuels is currently the subject of intense debate. In 2010, the Forest Guild is engaged in a comprehensive study commissioned by the Massachusetts Department of Energy Resources and led by Manomet Center for Conservation Sciences. Together with Manomet and other partners, we are investigating the impact of various forest practices on atmospheric carbon between managed and unmanaged forests. The results of this study will be available by June 2010 and will be used to expand this section on the carbon considerations for biomass harvesting. The Manomet study will model different biomass harvest scenarios to help determine which forest practices have less of an impact on the accumulation of atmospheric carbon.

In the interim, the following sections offer suggestions based on research that is currently available. It is important to recognize that in some cases a practice that contributes to a significant reduction in atmospheric carbon may be, or may appear to be, in conflict with considerations regarding biodiversity or long-term site productivity, as outlined in previous sections of this document. For example, while utilizing logging slash for energy may prove important in a scenario designed to reduce atmospheric carbon, the retention of some logging slash post harvest may also be important for the maintenance of forest productivity. In such cases, as in many areas of forestry, divergent goals must be balanced for the specific operating unit or ownership. As discussed in previous sections, the guidelines in this report are primarily intended to support decision making about the maintenance of ecological function and value in a forest management context.

Strategies that Improve the Carbon Budget on Managed Forests

Some forest management strategies can increase carbon sequestration rates and store more carbon over time than others. Silviculture that encourages the development of structural complexity stores more carbon than silvicultural methods that create homogenous conditions. Uneven-aged management is often used to promote a structurally complex forest and can sequester more carbon than less structurally complex forests managed with even-age methods. Even-aged management systems periodically remove most of the forest carbon. When used in existing mature forests they may have a greater negative carbon impact, particularly since near-term carbon emission reductions are most important. Where even-aged management systems are appropriate, encouraging advance regeneration, or retaining residual components of the original stand, may be the fastest way to build up or maintain forest carbon. Extending rotation length will also result in an increased mean carbon stocking volume and a potential increase in carbon in harvested wood products stored offsite.

The use of logging slash for energy production has a lower carbon impact than the use of live trees for energy because logging slash will decay and emit carbon and other greenhouse gases, while live trees will continue to sequester carbon. Similarly, since trees naturally die, decay, and emit carbon, harvests that focus on suppressed trees likely to die in the near future produce fewer carbon emissions overall than the harvest of trees that are healthier, sequester carbon faster, and have long life expectancies. By using biomass harvests to remove suppressed trees with shorter life expectancies, the remaining healthier trees, "crop trees," can grow faster and larger and produce higher-value products. These more valuable products have the potential to store carbon off-site longer than products with a shorter life cycle, such as paper or shipping pallets. These products also will meet human needs while emitting less carbon than alternatives such as steel or concrete. However, the harvest of future crop trees for energy is the worst case scenario: such a harvest reduces on-site carbon, probably limits the economic productivity of the stand, and reduces the opportunity to produce higher-value products that provide long-term carbon storage and displace more carbon-intensive products.

Determining the Carbon Impact of Biomass Harvesting

While the use of forest biomass for energy production can be helpful in mitigating climate change, accounting procedures for carbon mitigation programs must accurately account for all of the impacts of the proposed biomass use. The accounting should be based on a life cycle analysis that evaluates the effects of forest management and biomass removals on forest carbon . In order to determine the carbon impact of a biomass harvest, the analysis must include the following elements:

1. The amount of carbon removed from the site.

2. The amount of carbon used to grow, remove and transport the material to utilization.

3. The efficiency and carbon emissions of the use of forest biomass for energy, compared to business-as-usual (i.e., no biomass harvest) alternatives.

4. Future carbon sequestration rate for the site.

5. The impact of biomass removals on the site's capacity to grow forest products that store carbon or replace other carbon-intensive products.

6. The time required to re-sequester the carbon removed from the site and the time required to re-sequester the carbon that would have been sequestered in the business-as-usual scenario.

7. The business-as-usual scenario which includes

   a. Predicted harvest rates for the forest type and site in question

   b. Carbon emissions factors for the production, transportation, and use of the business-as-usual fuel, most likely a fossil fuel.

A full accounting that includes these elements can help answer complex questions regarding forest management and carbon impacts. For example, logging slash plays a number of functions. It is a valuable source of nutrients, provides biodiversity habitat, stores carbon on-site and is a potential source of renewable energy. Biomass retention guidelines provide targets for how much to retain for ecological reasons. But how much to remove as a renewable fuel versus how much to leave for on-site carbon storage can only be answered by comprehensive modeling of carbon flows over time.

Guidelines for Carbon Storage

- When managing for shade-tolerant and mid-tolerant species, a shift from even-aged to uneven-aged management will increase the retention of carbon on-site.
- When appropriate to the tree species, a shift to regeneration methods that encourage advanced regeneration, such as from clearcut to shelterwood, will retain carbon on-site for longer periods.
- Retain reserve trees or standards or delay their removal.
- Delay regeneration harvests or lengthen harvest cycles to grow trees for longer times and to larger sizes.
- Encourage rapid regeneration.
- Capture natural mortality as efficiently as possible while retaining adequate numbers of snags, decaying trees, and DWM.
- Use biomass harvests to concentrate growth on healthy crop trees that can be used to manufacture products that hold carbon for long periods or replace carbon-intensive products.

5. RESOURCES AND REFERENCES

BMPs and Other State Guides

- Maine's Woody Biomass Retention Guidelines http://www.maine.gov/doc/mfs/pubs/biomass_retention_guidelines.html
- Biodiversity in the Forests of Maine: Guidelines for Land Management http://www.maine.gov/doc/mfs/pubs/pdf/biodiversity_forests_me.pdf
- Vernal Pool Habitat Management Guidelines (Maine) http://www.maine.gov/doc/mfs/pubs/pdf/vernal_pool_hmg.pdf
- Good Forestry in the Granite State: Recommended Voluntary Forest Management Practices for New Hampshire http://extension.unh.edu/resources/files/Resource000294_Rep316.pdf
- Acceptable Management Practices for Maintaining Water Quality on Logging Jobs in Vermont http://www.vtfpr.org/watershed/documents/Amp2006.pdf
- Massachusetts Forestry Best Management Practices Manual http://www.mass.gov/dep/water/drinking/forstbmp.pdf
- Connecticut Best Management Practices for Water Quality while Harvesting Forest Products http://www.ct.gov/dep/cwp/view.asp?A=2697&Q=379248
- Northeast Master Logger Certification Program http://www.masterloggercertification.com/
- Natural Fuels Photo Series http://depts.washington.edu/nwfire/dps/

Forest Guild Reports

- Ecology of Deadwood in the Northeast
- www.forestguild.org/publications/research/2010/ecology_of_deadwood.pdf
- An Assessment of Biomass Harvesting Guidelines www.forestguild.org/publications/research/2009/biomass_guidelines.pdf
- Synthesis of Knowledge from Biomass Removal Case Studies www.forestguild.org/publications/research/2008/Biomass_Case_Studies_Report.pdf
- A Market-Based Approach to Community Wood Energy: An Opportunity for Consulting Foresters www.forestguild.org/publications/research/2008/Market_Based_CWEP_Approach.pdf

REFERENCES

1 Benjamin, J. G. 2010. *Considerations and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine*. Miscellaneous Publication 761, University of Maine, Maine Agricultural and Forest Experiment Station, Orono, ME

2 Bradford, J., P. Weishampel, M.-L. Smith, R. Kolka, R. A. Birdsey, S. V. Ollinger, and M. G. Ryan. 2009. Detrital Carbon Pools in Temperate Forests: Magnitude and Potential for Landscape-Scale Assessment. *Canadian Journal of Forest Research* 39(4):802–813

3 Duvall, M. D., and D. F. Grigal. 1999. Effects of Timber Harvesting on Coarse Woody Debris in Red Pine Forests across the Great Lakes States, USA. *Canadian Journal of Forest Research* 12(29):1926-1934

4 Evans, A. M., and M. J. Kelty. 2010. *The Ecology of Dead Wood in the Northeast*. Forest Guild, Santa Fe, NM

5 Evans, A. M., and R. T. Perschel. 2009. *An Assessment of Biomass Harvesting Guidelines*. The Forest Guild, Santa Fe, NM

6 Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. *Biodiversity in the Forests of Maine: Guidelines for Land Management*. University of Maine, Cooperative Extensive, Orono, ME

7 Goodburn, J. M., and C. G. Lorimer. 1998. Cavity Trees and Coarse Woody Debris in Old Growth and Managed Northern Hardwood Forests in Wisconsin and Michigan. *Canadian Journal of Forest Reseach* 28:427–438

8 Gore, J. A., and W. A. Patterson, III,. 1986. Mass of Downed Wood in Northern Hardwood Forests in New Hampshire: Potential Effects of Forest Management. *Canadian Journal of Forest Research* 16(2):335-339

9 Hallett, R. A., and J. W. Hornbeck. 2000. Managing Oak and Pine Stands on Outwash Sands: Protecting Plant Nutrients. *Northern Journal of Applied Forestry* 17(2):57-61

10 Heath, L. S., and D. C. Chojnacky. 2001. *Down Dead Wood Statistics for Maine Timberlands*, 1995. RB-NE-150, Forest Service, Northeastern Research Station, Newtown Square, PA

11 Herrick, S., J. Kovach, E. Padley, C. Wagner, and D. Zastrow. 2009. *Wisconsin's Forestland Woody Biomass Harvesting Guidelines.* PUB-FR-435-2009, WI DNR Division of Forestry and Wisconsin Council on Forestry, Madison, WI

12 Idol, T. W., R. A. Figler, P. E. Pope, and F. Ponder. 2001. Characterization of Coarse Woody Debris across a 100 Year Chronosequence of Upland Oak-Hickory Forests. *Forest Ecology and Management* 149(1-3):153-161

13 Kenefic, L. S., and R. D. Nyland. 2007. Cavity Trees, Snags, and Selection Cutting: A Northern Hardwood Case Study. *Northern Journal of Applied Forestry* 24(3):192-196

14 McCarthy, B. C., and R. R. Bailey. 1994. Distribution and Abundance of Coarse Woody Debris in a Managed Forest Landscape of the Central Appalachians. *Canadian Journal of Forest Research* 24(7):1317–1329

15 McGee, G. G. 2001. Stand-Level Effects on the Role of Decaying Logs as Vascular Plant Habitat in Adirondack Northern Hardwood Forests. *The Journal of the Torrey Botanical Society* 128(4):370-380

16 McGee, G. G., D. J. Leopold, and R. D. Nyland. 1999. Structural Characteristics of Old-Growth, Maturing, and Partially Cut Northern Hardwood Forests. *Ecological Applications* 9(4):1316-1329

17 MFRC. 2007. *Biomass Harvest Guidelines.* Minnesota Forest Resources Council, St. Paul, MN

18 Roskoski, J. P. 1977. *Nitrogen Fixation in Northern Hardwoods Forests*. Yale University, New Haven, CT

19 Smith, C. Y., M. T. Moroni, and I. G. Warkentin. 2009. Snag Dynamics in Post-Harvest Landscapes of Western Newfoundland Balsam Fir-Dominated Boreal Forests. *Forest Ecology and Management* 258(5):832-839

20 Taylor, A. R., J. R. Wang, and H. Y. H. Chen. 2007. Carbon Storage in a Chronosequence of Red Spruce (Picea Rubens) Forests in Central Nova Scotia, Canada. *Canadian Journal of Forest Research* 37(11):2260–2269

21 Tritton, L. M. 1980. *Dead Wood in the Northern Hardwood Forest Ecosystem*. Yale University, New Haven, CT

22 Tritton, L. M., C. W. Martin, J. W. Hornbeck, and R. S. Pierce. 1987. Biomass and Nutrient Removals from Commercial Thinning and Whole-Tree Clearcutting of Central Hardwoods. *Environmental Management* 11(5):659-666

23 Tritton, L. M., and T. G. Siccama. 1990. What Proportion of Standing Trees in Forests of the Northeast Are Dead? *Bulletin of the Torrey Botanical Club* 117(2):163-166

24 Tubbs, C. H., R. M. DeGraaf, M. Yamasaki, and W. M. Healy. 1987. *Guide to Wildlife Tree Management in New England Northern Hardwoods*. GTR-NE-118, US Forest Service, Northeastern Forest Experiment Station, Broomall, PA

25 Woodall, C. W., and V. J. Monleon. 2008. *Sampling Protocol, Estimation, and Analysis Procedures for the Down Woody Materials Indicator of the Fia Program*. NRS-GTR-22, U.S. Forest Service, Newtown Square, PA

26 Woodley, S. 2005. Snag and Cavity Tree Retention. Pages 61-64 in M. G. Betts and G. J. Forbes, editors. *Forest Management Guidelines to Protect Native Biodiversity in the Greater Fundy Ecosystem.* New Brunswick Co-operative Fish and Wildlife Research Unit, University of New Brunswick, Fredericton, NB

APPENDIX 5

SUMMARY OF PUBLIC INPUT TO STUDY

The intent of the public meeting held on December 17, 2009 in Holyoke, Massachusetts was:

1) to share information about the study and the questions it will address; and

2) solicit public input about additional questions the research team should consider (within the scope of the DOER RFP).

Nearly 200 people attended the public meeting. Following an overview presentation, those that were interested in providing input were broken into to small groups where the questions and comments were recorded and reported out. Those questions and comments are contained in the table below. The team reviewed these inputs and addressed those that were relevant to the study and within the scope of what DOER asked the team to assess. Additional input was solicited via the internet. The internet site was meant to be a venue for the submission of additional comments and not a forum for discussion with the study team. Maintaining an ongoing public dialogue during the study was outside the scope and budget of the study commissioned by DOER.

Outside of the public meeting, many additional submissions of comments, opinion, technical resources, and relevant articles were also submitted to the team and distributed to the appropriate subject matter expert. Submissions were made by a range of concerned citizens, organizations, and technical experts.

Comments/Questions developed during small group breakout sessions at December 17, 2009 input meeting in Holyoke, MA (note: several submissions were illegible)	
Comment	**Category**
Why weren't researchers working on this issue in west included on panel?	Comments/Questions to DOER
Will each of these questions be explicitly dealt with in a public way?	Comments/Questions to DOER
Why aren't they looking at emissions/pollution?	Comments/Questions to DOER
How is study being coordinated with adjacent states?	Comments/Questions to DOER
If we gave this level of scrutiny to every other power producer, would anything get built?	Comments/Questions to DOER
Are new technologies (such as combined heat and power) being encouraged for existing power plants?	Comments/Questions to DOER
Can (we) guarantee exactly what emissions are emitted?	Comments/Questions to DOER
Sustainable communities - where is power going? (local or distant)	Comments/Questions to DOER
What happens when the wood runs out, will you turn to waste? Trash? And are there adequate standards in place to govern trash?	Comments/Questions to DOER
What if your assumptions and study results are wrong and the biomass plants are built?	Comments/Questions to DOER
What if your assumptions are based on sustainable harvesting and there is no enforcement after the plants are built, and illegal clearcuts are rampant?	Comments/Questions to DOER
Why isn't this being run as a MEPA Study?	Comments/Questions to DOER
Will you also consider water resources needed for biomass electric?	Comments/Questions to DOER
Are they delaying biomass plants until these studies are done? If not, what is the purpose of these studies? Can't this be studied in lab or research? What if state is [?] without proper data?	Comments/Questions to DOER
What is states statutory authority to ban issuance of new qualifications for REC and effect on ongoing biomass projects? Need explanation of RPS in MA and neighbors. Address electricity market fundamentals as it drives biomass.	Comments/Questions to DOER
Adequacy of DCR to oversee forest cutting on private lands and state & capacity to expand question to other states.	Comments/Questions to DOER
What can be done to prevent invasive species transfer with increasing wood transport of other tree parts?	Comments/Questions to DOER
Why won't the state halt existing permitting process for biomass while study in progress instead of issuing permits in environment of uncertainty?	Comments/Questions to DOER

How can the state prevent clustering of incinerators?	Comments/Questions to DOER
When are sociological impacts of biomass to be studied?	Comments/Questions to DOER
Why are there four proposals at this time for biomass plants?	Comments/Questions to DOER
What are the impacts of biomass plants on river ecology and water resources?	Comments/Questions to DOER
How can you be permitting the plants before the sustainability has been determined?	Comments/Questions to DOER
Is there a regional solution to biomass plants?	Comments/Questions to DOER
This is all second growth forest, why cut and destroy the best carbon sequesters we have (which don't charge)?	Comments/Questions to DOER
The wind blows for free, how much do you charge?	Comments/Questions to DOER
If 1/3 of biomass in MA is proposed to use construction and demolition debris, then why are we only studying woody forest biomass?	Comments/Questions to DOER
Will you examine the impact of increased biomass harvesting on the economics of tourism and recreation that exists in western MA?	Comments/Questions to DOER
Please consider the possibility of a statewide referendum in 2012 to stop all logging on public lands.	Comments/Questions to DOER
Why do we need biomass?	Comments/Questions to DOER
Carbon accounting of corporate energy consumption vs. future energy consumption.	Comments/Questions to DOER
What will harvesting of forests do to tourism industry?	Comments/Questions to DOER
What are the consequences of continued over-reliance on fossil fuels vs. various biomass scenarios?	Comments/Questions to DOER
With overall electric consumption projected to go down, why do we need biomass plants?	Comments/Questions to DOER
Why not put subsidies to conservation or non-emission technologies?	Comments/Questions to DOER
Will Governor be able to take wood from private lands by eminent domain?	Comments/Questions to DOER
How can we allow biomass combustion when we cannot remove particulate matter < 2.5?	Comments/Questions to DOER
Concern if RECs for sustainable forestry for biomass, then we'll lose control of forest.	Comments/Questions to DOER
Who will answer the question about human health?	Comments/Questions to DOER
90% of the energy used in MA is from fossil fuels, 4.5% from hydro. Wind and solar are minimal. If we can't use biomass, then how will we get to the 10% RPS? What's the solution for getting off fossil fuels?	Comments/Questions to DOER
When and how, if at all, will the state address it's August, 2009 decision to only include waste sources in the renewable fuel standard? What about non-food energy crops? Cellulosic ethanol? Algae and direct-to-fuel microbes and processes? Is this study going to be the main input to the state's stance on biofuel feedstocks? If so, then why is the focus only on forests and wood? What about fallow lands? Non-thermal transformation of feedstocks and other advanced technologies?	Comments/Questions to DOER
Have they considered the ballot initiative where sufficient signatures were just collected fort the 2010 ballot and the fact that if it passes, incinerators will not be eligible for renewable energy credits and how this will impact the economics of the biomass effort? Related: citizen consideration of a similar ballot in 2012 for prohibition of all logging on public lands?	Comments/Questions to DOER
Will the research address the advisability of any biomass harvesting or removal first? All other questions follow.	Comments/Questions to Team
What is the definition of clearcutting (is it prohibited, is it proceeding?)?	Comments/Questions to Team
Are you aware state not FSC cert and has not been since April 10th? And there are serious conditions open on their forestry practices?	Comments/Questions to Team

Water quality and hydrology issue?	Comments/Questions to Team
How much non-renewable energy is used to produce renewable energy?	Comments/Questions to Team
Clean wood vs. construction/demo wood	Comments/Questions to Team
Alternative transportation of wood opportunities.	Comments/Questions to Team
Nitrogen cycles/methane cycles. How are they affected by biomass harvesting?	Comments/Questions to Team
How will biomass harvesting (removal of organic matter) affect acid rain impacts on forest soil?	Comments/Questions to Team
Where will you get your information on the technological aspects of burning biomass?	Comments/Questions to Team
How will biomass harvesting contribute to the spread of invasive species?	Comments/Questions to Team
Silvicultural perspective - what markets other than biomass are there for low grade wood?	Comments/Questions to Team
Is there a realistic time frame for the scope of study? Is there a way to address the time issue?	Comments/Questions to Team
How are they defining "forest health" and "forest sustainability"?	Comments/Questions to Team
Where will the displaced animals go?	Comments/Questions to Team
Incentives to landowners?	Comments/Questions to Team
Shifting balance of renewable?	Comments/Questions to Team
Will you consider energy security of local fuel?	Comments/Questions to Team
What are the positions of the Audubon Society and other environmental groups on biomass energy?	Comments/Questions to Team
Need to consider project finance implications in order to avoid considering unfeasible options or recommendations.	Comments/Questions to Team
Will DOER-funded SFBI studies be considered/utilized?	Comments/Questions to Team
Look at long experience with biomass energy in New England (especially southern NH).	Comments/Questions to Team
Look at other uses of biomass (ethanol etc.).	Comments/Questions to Team
Are BMPs required to be followed on public land? Concern they have not been followed in the past consistently.	Comments/Questions to Team
Where are you drawing the circle for supply of biomass per plant? Is it limited to 50 mile radius for each plant? Are you looking at a limit on plants with regard to supply (e.g., when several new plants are proposed and there are existing plants)?	Comments/Questions to Team
Are they considering pyrolysis as an alternative technology?	Comments/Questions to Team
Are you comparing biomass to other renewables or only to carbon based fuels?	Comments/Questions to Team
Are they starting with an hypothesis or asking questions without an hypothesis? What method are they using - published sources - for answering questions? Are they bringing a bias that they are trying to prove as true?	Comments/Questions to Team
Whate about the impact on wood prices? Are the changes in prices being considered in the economic impact analysis? The mix of biomass sources could change in price and so could carbon.	Comments/Questions to Team
Is there representation on the team from agricultural interests? Look at impacts on farmland.	Comments/Questions to Team
What about non-forest biomass resources? Are they being considered?	Comments/Questions to Team
What about infrastructure limits? (e.g., we have XX tons/day - but no way to get it to where [facilities are]).	Comments/Questions to Team
Are the total scope of impacts being considered? Co-firing issue needs to be taken into account more fully.	Comments/Questions to Team

NY study - How will their results affect our study? Or be taken into account as we embark on this?	Comments/Questions to Team
What is the geography being studied - just within Massachusetts?	Comments/Questions to Team
Are other pollutants being considered besides carbon (e.g., black carbon)?	Comments/Questions to Team
Are you factoring in the impacts of climate change over the next 50 years when evaluating the resource?	Comments/Questions to Team
BMPs are based on historical records.	Comments/Questions to Team
Are you considering energy to dry biomass?	Comments/Questions to Team
Why wasn't the study done prior to permitting plants?	Comments/Questions to Team
Are you looking at all scale technologies (e.g., home wood stoves) or only on larger-scale institutional level?	Comments/Questions to Team
Are you considering that biomass may not be sustainable or a good idea for harvesting for energy at all?	Comments/Questions to Team
After you establish the baseline, could you then create a model that would examine the impact of a biomass plant within 50-75 miles radius of the plant and compare the environmental impact of biomass to the other fuel sources used within that region, like wind, hydro, coal, oil, etc., and not include areas with no proposed biomass plants?	Comments/Questions to Team
Will this report dive right in or preface with layperson friendly terms and fundamental terms? Providing something accessible to public including life cycle of a tree and forest as it relates to carbon sequestration.	Comments/Questions to Team
Will they share report on progress or black box final issue?	Comments/Questions to Team
Existing Pine Tree Biomass already burning biomass. Are they addressing the draw of biomass plants to pull in new wood products? Do we need additional constraints on any plant? Need to address impossibility of ensuring fuel specifications.	Comments/Questions to Team
Will baseline study - look at each energy source, compare sustainability, renewability and carbon consequences including conservation, solar, efficiency, wind.	Comments/Questions to Team
See how more advanced country (Japan, Scandinavia, etc.) have dealt with biomass reducing fossil fuel.	Comments/Questions to Team
Climate models see MA as warmer - more erratic weather. Potential of drought to kill forest if too dense. Will model consider drought effect on unmanaged forest?	Comments/Questions to Team
Can the team openly address skepticism toward state and skepticism about panel members' past activities as a delay tactic. Biomass developers have applauded this study.	Comments/Questions to Team
Address biochar benefits/feasibility.	Comments/Questions to Team
When studying levels of carbon sequestration in between managed and unmanaged forest, distinguish "poorly managed forest" from "well managed forest".	Comments/Questions to Team
Will you study different biomass harvesting systems (i.e., cut-to-length vs. whole tree) in terms of stand damage, soil nutrient levels, and democratizing access to biomass markets (i.e., allowing all loggers to participate in the market, not just those with expensive logging/chipping systems) - This would require new biomass plants to accept round wood.	Comments/Questions to Team
Assessing amount of clean wood waste generated (i.e., tree trimming; ice storm wood; sawmill remains; waste pallets; secondary manufacturing waste; roadside trimming).	Comments/Questions to Team
Full transparency of funding sources of the members of the study group.	Comments/Questions to Team
Define "biomass". Is it woody biomass?	Comments/Questions to Team
Consider pyrolysis as technology.	Comments/Questions to Team
Consider methane production from natural forest decomposition.	Comments/Questions to Team
Assess the impact of residential use of biomass vs. commercial use of biomass.	Comments/Questions to Team

Will MA DFW goals of early successional habitat creation be considered?	Comments/Questions to Team
Regulations by basal area. Is this the best way to regulate whole tree harvesting?	Comments/Questions to Team
Are you considering that management on stand land may change?	Comments/Questions to Team
What capacity of mechanized operators will be required?	Comments/Questions to Team
It is not just a question of "sustainability". Is it a good idea to burn forests when we have too much pollution, too much carbon in the atmosphere, and already stressed forests.	Comments/Questions to Team
What is the impact of biomass market on incentives for private forest landowners? Will this help keep forest land in forests?	Comments/Questions to Team
Add other indicators of forest health.	Comments/Questions to Team
What were the positions of the consultants on biomass prior to being commissioned for this study?	Comments/Questions to Team
Research Question 2 may want to factor in diesel and gasoline truck transportation of forest fuels to the biomass plants as that relates to sustainability.	Comments/Questions to Team
How many invasive species will come to visit when we truck in wood from the whole northeast? Worcester has had to euthanize a whole bunch of its trees.	Comments/Questions to Team
Will you look at the impact of increased wood harvesting for biomass on the market for firewood? A concern in Franklin County is that the wood market will drive up the price of firewood for people who rely on it to heat.	Comments/Questions to Team
How is waste biomass byproduct factored into biomass equation?	Comments/Questions to Team
More clarification on assumptions in study.	Comments/Questions to Team
Why so many men on the study team?	Comments/Questions to Team
Will efficiency of different biomass energy technologies be taken into consideration?	Comments/Questions to Team
What are environmental and economic impacts of inefficient combustion of biomass?	Comments/Questions to Team
Will building/construction of power plants be factored into LCA?	Comments/Questions to Team
Will biomass harvesting be like strip mining and how do we prevent it?	Comments/Questions to Team
Consider indirect impacts in addition to land impacts.	Comments/Questions to Team
Balance effect of development and managed forests.	Comments/Questions to Team
Is construction and demolition material included in the study?	Comments/Questions to Team
Will the policy address the need for innovation in bioenergy and recognize new technologies such as gas pyrolysis and alternative feedstockes such as wastewood, construction debris, etc.	Comments/Questions to Team
Is construction and demolition material included in the consideration for the study?	Comments/Questions to Team
How much trucking will there be and how will that affect local traffic patterns and the quality of life? What is the energy impact of the trucking and will that be considered as part of the life-cycle analysis? Why are four plants so close together all being proposed at the same time and where will the wood come from?	Comments/Questions to Team
Indirect impacts – in addition to the land impacts, what is the environmental cost of the "growth induced impacts"? (such as the growth of the local economy?	Comments/Questions to Team
How can we balance the effect of development versus managed forests. What will be the land ownership incentive? The incentive to hold land in private hands? If we become too restrictive, then people will not be able to earn income from their land and have to sell off to developers. Concern about incentives for land ownership. Also, concern if REC's for sustainable forestry for biomass are impacted, then we will lose control of our forests.	Comments/Questions to Team

Request to include long-term anthropological perspective of human forest use in the area and how social and economic situations, values, etc. affect the use of forest. Going all the way back to native American Indians; through colonial times, to industrialization to the present. (editor comment: are we so vain as to think we will leave no heritage)?	Comments/Questions to Team
What is the H2O content of the wood being considered?	Comments/Questions to Team
Are we going to include extreme scenarios in the baseline such as a complete cut-off of foreign oil (i.e. middle east nuclear scenario) and the ability of the state (and the country) to continue to function? Will an extreme case be included in the baseline?	Comments/Questions to Team
How will more smaller plants with more lax air quality regulations and controls affect health?	Public Health Concerns
Look at health issues.	Public Health Concerns
Will you be looking at the broadest range possible of forest health indicators? Should make sure to also overlay analysis with the other detailed biodiversity planning in state, including Woodlands and Wildlands and TNC Ecoregional Plans.	Public Health Concerns
Call on state to address the medical society's statement that biomass incinerators pose unacceptable health risks.	Public Health Concerns
Why propose biomass within city limits or in a valley with a high percentage of respiratory illness? Are you mad?	Public Health Concerns
Air quality changes from biomass.	Public Health Concerns
Fine particulate given off by large trucks and impact on air quality.	Public Health Concerns
Other emissions from biomass combustion (other health impacts).	Public Health Concerns
What will happen to remnants from burning – the ash? Will there be environmental problems from it?	Public Health Concerns
Who will answer the question about human health and local environments? These plants are in low-lying valleys with poor air circulation and bad air quality already. What about the local climate and weather and current health issues (such as already high cancer rates)?	Public Health Concerns