The State of Biomass Energy

The State of Wood Biomass Energy in Maine

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"The State of Wood Biomass Energy in Maine" is the third chapter in *The State of Maine's Environment 2010*, a report produced by the Environmental Policy Group in the Environmental Studies Program at Colby College in Waterville, Maine. This is the sixth State of Maine's Environment report published since 2004.

Executive Summary

With 86% of state land classified as timberland, Maine is in a unique position to pursue large-scale wood biomass energy initiatives. In the long term, biomass provides cheaper, cleaner energy than do fossil fuels, and conversion of existing facilities will return money currently spent on imported fossil fuels to Maine's core forestry sector. Furthermore, life cycle analyses estimate that biomass energy emits 9-21 times less life-cycle carbon emissions than do fossil energy sources, making it a favorable choice with regards to contributions to climate change. Threats to forest health can be minimized by responsible forest management and nutrient supplementation. Considering economic, ecological, and public health concerns, wood biomass energy shows significant promise as a sustainable energy source for the state of Maine. We recommend that Maine continue to support the conversion of fossil fuel generators to wood biomass energy through proactive policy measures, and that it also continue to promote Best Management Practices for forestry in order to ensure long-term forest health, and sustainability of biomass as a major energy source. Pollution from biomass facilities should be restricted and monitored, and policy measures should focus on encouraging the co-generation of heat and electricity in order to maximize efficiency of resource use.

Introduction

Given international concern over climate change and high global energy demands, concerns of carbon emissions and sustainability of resources are pressing (IPCC 2007). Recent oil price instability has further raised the demand for renewable energy sources. Biomass, the combustion of organic matter for the production of heat and/or electricity, is the largest domestic source of renewable energy, surpassing even hydropower (Perlack, Wright et al. 2005). In 2003, biomass supplied over 3% of total energy consumption in the US, mostly through industrial heat and steam production by the pulp and paper industry, as well as electrical energy from forest industry residues and municipal solid waste (MSW) (Perlack, Wright et al. 2005). Biomass energy is also an attractive energy source because it provides jobs and supports the local economy, thereby increasing energy independence.

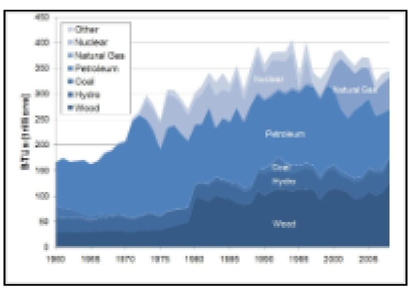

Figure 3.1 Energy consumption by source in Maine (EIA 2010a)

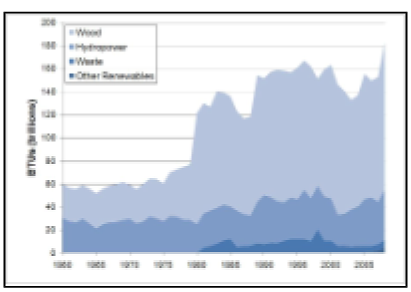

Figure 3.2 Renewable energy consumption by source in Maine (EIA 2010a)

Biomass and Maine

In Maine, biomass comprises 35% of total energy consumption and 70% of renewable energy consumption (Figs 3.1 and 3.2). Maine's vast forest resources – it is nearly 90% forested – make it well-suited for the production of biomass energy. Of this forestland, 97% is available timberland, making Maine the most forested state, and giving it an advantage over all other states (Figs 3.3 and 3.4) (USFS 2008). Furthermore, most of Maine's forest lands, including conservation land, preserve logging rights, which contribute to the high percentage of timberland.

The forest product sector makes up an important part of Maine's economy, employing over 18,000 people (Innovative Natural Resource Solutions 2005). Maine's well-established forest products industry makes the state better prepared for adoption of biomass energy because it already has the necessary infrastructure and equipment, knowledge of management practices, and a trained labor force.

Lastly, biomass energy has recently received political recognition, which has led to economic incentives for conversion from fossil fuel to renewable energy use, including biomass energy, at both the state and national levels. In 2008, Maine governor Baldacci introduced the Governor's Wood-to-Energy Initiative. This program promotes converting public buildings to wood biomass heat, encourages homeowners to switch from oil heat to heat from renewable energy sources, and promotes Maine-grown alternative energy industries (Wood-to-Energy Task Force 2008).

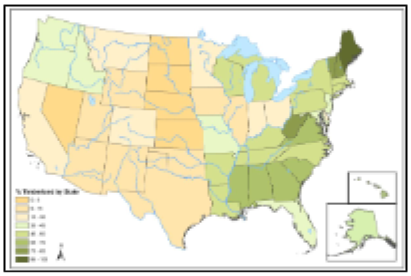

Figure 3.3 Percent timberland by state (Smith, Miles et al. 2009)

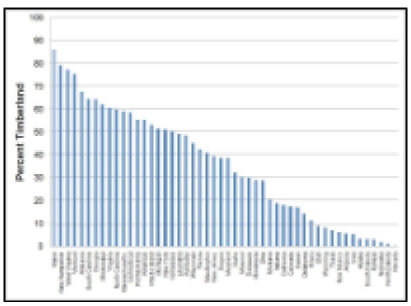

Figure 3.4 Percent timberland by state (Smith, Miles et al. 2009)

This report specifically focuses on wood biomass used in industrial-scale projects that produce heat and/or electricity. It excludes small-scale home heating with wood or wood pellet stoves because of the lack of data available on this sector.

History of Biomass

Biomass is the oldest fuel source to have been harnessed by humans. Historically, wood, grass, straw, grain chaff, and animal dung were popular fuel sources because they were accessible, easily flammable, and could be stored for long periods of time (Rehder 2000). Wood for fuel was usually air dried for several months before combustion, depending on the type of wood and its water content. However, ancient humans used far less energy than they do today; it has been estimated that ancient humans used approximately 5,000 kc/day in food and fuel, while by the late 20th century the average person used 270,000 kc/day, thereby greatly increasing society's demand for fuel. In the United States, wood was used as a primary fuel source through the 19th century (Rehder 2000).

In the US in the 1890s, coal began to replace wood as the primary fuel used in steam generation, and by 1910 its use had surpassed that of wood in urban homes, although some rural homes still continue to rely on wood for heat (CCEI 2010). Currently, the US relies heavily on coal, natural gas, and petroleum products to generate electricity and heat, and to power transportation (EIA 2010b).

Industrial biomass has developed independently of society's transition away from wood as a home fuel. In the 1970s, as environmental awareness grew in the US, researchers began to investigate the potential use of wood and biomass as an industrial heat and energy source, and by the 1980s biomass plants were becoming more common in the US (CCEI 2010). Currently, biomass energy makes up 10.5% of the global energy use, over three times the percentage used by the US.

Today, the state of Maine contains enough wood-fired biomass facilities to generate 2.1 million megawatt hours of energy per year, enough to power 21,000 homes. The power plants provide jobs for 1,000 Maine residents, and consume 3 million tons of wood annually (Aird and Cleaves

2010).

Objectives

This report evaluates the state of wood biomass energy in Maine by first discussing the legal and institutional framework around wood biomass energy. We evaluate the sustainability of wood biomass energy in terms of its ecological and human impacts. We also evaluate the potential for future development of wood biomass energy. Finally, we discuss the implications of the findings for the future of wood biomass energy in Maine and present possible future scenarios and policy recommendations.

Methods

We reviewed literature from scientific publications and government reports available online. Data for this report were gathered from the US Forest Service, US Energy Information Association, Maine Forest Service and US Environmental Protection Agency, among other sources. We used ArcGIS 9.3 software to create maps showing biomass facilities in Maine and timberland in the US. We also used Microsoft Excel to create graphs.

Laws and Institutions

Because wood biomass energy affects the economy, the environment, and human health, numerous national and state laws regulate the industry (Tables 3.1 and 3.2). This legislation can be grouped into three broad categories: energy-related, resource-related, and health-related laws.

Energy-related legislation generally promotes the use of biomass as a renewable energy source. This is achieved through research, economic incentives, and direct grants to create or support wood biomass energy facilities. The American Recovery and Reinvestment Act of 2009, for instance, included a provision for a grant of over $11 million to assist in wood biomass energy installations in Maine public facilities. Other legislation that falls into this category includes Maine's Renewable Portfolio Standard (1999), the Biomass Research and Development Act (2000), the Energy Policy Act (2005), and the USDA Renewable Energy for Rural America Program (2009) (Tables 3.1 and 3.2).

Resource-related legislation manages the use of forest resources to ensure not only the longevity of forests but also the sustainability of the resources they provide. This legislation includes the Healthy Forest Restoration Act (2003), which aims to thin and manage overstocked forest stands. State of Maine forestry legislation includes the Forest Regeneration and Clear Cutting Standards of 2009 and the Maine Forest Practices Act of 2004 (Table 3.2).

The third category of federal and state legislation is health-related and aims to regulate emissions from polluters. The oldest of these is the Clean Air Act (1970), which establishes ambient air quality standards and issues permits to polluting facilities. The Occupational Health and Safety Act regulates the safety of workers, particularly in workplaces that may be potentially hazardous, such as energy facilities.

Table 3.1 National legislation impacting biomass energy

Law	**Year**	**Description**	**Location**
Clean Air Act	1970	Establishes ambient air quality standards and permit systems for polluters. Portions related to biomass include National Ambient Air Quality Standards (NAAQS) and New Source Review (NSR) permits	42 USC 7401 et seq.
Occupational Safety & Health Act (OSHA)	1970	Ensures employees' rights to a safe working environment; includes stipulations regarding hazardous materials, excessive heat or cold, noise levels and mechanical dangers	29 USC 651 et seq.

Clean Water Act	1972	Regulates emissions of water pollution, and sets water quality standards for surface waters. Requires permits for point sources to discharge pollutants into navigable waters; polluters apply for permits from the National Pollutant Discharge Elimination System (NPDES)	33 USC 1251 et seq.
Hazardous Materials Transportation Act (HMTA)	1975	Regulates the transportation of hazardous materials, which may include biomass ash depending on the material used as fuel	49 USC 5101-5128
Emergency Planning and Community Right-to-Know Act (EPCRA)	1986	Creates safety standards for communities to protect public health and safety and the environment from toxic emissions and chemical hazards; may be relevant to biomass depending on the type of waste generated and pollution that is released into the air. The Toxic Chemical Release Reporting (40 CFR 372) requires that toxic chemical releases are reported	42 USC 11001 et seq.
Pollution Prevention Act (PPA)	1990	Established the EPA office of pollution prevention, and sets cost-effective standards for reducing pollution from point sources	42 USC 13101 et seq.
Biomass Research and Development Act	2000	Created the Biomass R & D Board to promote bio-based fuels through Federal grants and assistance, and guide federal strategic planning	7 USC 7624
Healthy Forests Restoration Act	2003	Created to thin overstocked stands, clear away vegetation and trees to create shaded fuel breaks, provide funding and guidance in response to massive forest fires in 2002	16 USC 6501 et seq.
Energy Policy Act	2005	Sets forth an energy research and development program covering: (1) energy efficiency; (2) renewable energy; (3) oil and gas; (4) coal; (5) Indian energy; (6) nuclear matters and security; (7) vehicles and motor fuels, including ethanol; (8) hydrogen; (9) electricity; (10) energy tax incentives; (11) hydropower and geothermal energy; and (12) climate change technology	42 USC 15801

American Recovery and Reinvestment Act: Public Building Wood-to-Energy program	2009	Includes a $11.4 million grant to assist in wood-to-energy installations in Maine public facilities	26 USC 25C
USDA Renewable Energy for Rural America Program	2009	A section in the American Recovery and Reinvestment Act, which offers financial incentives for rural renewable energy projects	7 USC 8107

Table 3.2 State legislation impacting biomass energy

Law	Year	Description	Location
Maine's Tree Growth Tax Law	1972	Incentivizes use of Woodland Management Plans	36 MRSA §571 - 584-A.
Voluntary Renewables Resources Grants	1997, 1998	Provides grants to non-profit and community organizations for the development of renewable energy	35-A MRSA §3210; ME PUC 65.407, c. 312
Forest Regeneration and Clearcutting Standards	1999	Requires that all commercial timber harvesting is reported to the Maine Department of Conservation and the Bureau of Forestry, and sets standards for separation zones between clear cuts	12 MRSA c. 805, sub-c. III-A
Renewable Portfolio Standards	1999	Set a standard that 30% of energy generation sold in Maine be from renewable sources	35-A MRSA c. 32. §3210
Maine Forest Practices Act	2004	Regulates timber harvesting in areas surrounding rivers, streams, ponds, wetlands, and tidal waters	12 MRSA p.11, c.805
Maine Renewables Portfolio Goal	2006, 2007	Requires an additional 10% of new renewable energy capacity by 2017	35-A MRSA § c. 3210; CMR 65-407-311
The Efficiency Maine Trust Act	2009	Establishes the Efficiency Maine Trust responsible for Maine's energy efficiency and renewable energy programs	35-A MRSA c.97

Stakeholders

Stakeholders can be split into two categories: primary and secondary (Benjamin, Lilieholm et al. 2009). Primary stakeholders are those most directly involved with the production of biomass energy, through the forestry and incineration process. The primary parties bear the brunt of the burden in terms of supply, meaning they must adjust forest management plans, update equipment to be appropriate for biomass production-specific uses, train staff, and otherwise prepare for the increase in production. They also may receive the largest economic benefits from the industry, as they will be selling in a newly expanded market. Among the primary stakeholders are the forestland owners, loggers, truckers, processors, and biomass facility employees. The secondary stakeholders are those indirectly affected by biomass energy production and consumption. They are comprised of the general population of Maine, local governments, civic organizations, environmental non-governmental organizations, and businesses. These parties are also ultimately involved in the biomass industry, as consumers, regulators, critics, and competitors to the biomass energy sector.

State of Topic

Maine currently has 23 industrial scale biomass facilities listed on the Energy Information Administration (EIA) online database. These facilities run solely on biomass chips or co-fire with one other source (see Tables 3.3, 3.4). Their locations show no relationship to population centers or working forests (Fig 3.5).

Table 3.3 Listed co-firing biomass facilities in Maine (EIA 2008)

Plant Name	Town	Capacity (mW)	Initial Year	Co-Fire Source
Somerset Plant	Skowhegan	115.0	1990	Black Liquor
S D Warren Westbrook	Westbrook	63.3	1982	Coal
East Millinocket Mill	East Millinocket	57.8	1954	Residual Fuel Oil
Domtar - Woodland Mill	Baileyville	46.0	1966	Black Liquor
Boralex Stratton Energy	Cumberland	44.3	1989	Distillate Fuel Oil
Boralex Beaver Livermore Falls	Livermore Falls	35.8	1992	Other Biomass Solids
Boralex Ashland	Ashland	34.0	1993	Distillate Fuel Oil
Lincoln Paper & Tissue	Lincoln	15.5	1957	Black Liquor

Table 3.4 Listed single-source biomass facilities in Maine (EIA 2008)

Plant Name	Town	Capacity (mW)	Initial Year
Boralex Fort Fairfield	Fort Fairfield	31.0	1987
Indeck Jonesboro Energy Center	Jonesboro	26.1	1987
Indeck West Enfield Energy Center	West Enfield	25.7	1987
Worcester Energy	Deblois	22.0	1989
Boralex Sherman LLC	Stacyville	21.0	1986
Greenville Steam	Greenville	19.0	1988
Red Shield Environmental Old Town Facility	Old Town	14.0	1987
Lavalley Lumber LLC	Sanford	1.3	1989
Robbins Lumber	Searsmont	1.1	1981
J & L Electric	Strong	0.9	1980
Perma Treat Corporation	Mattawamkeag	0.5	1992

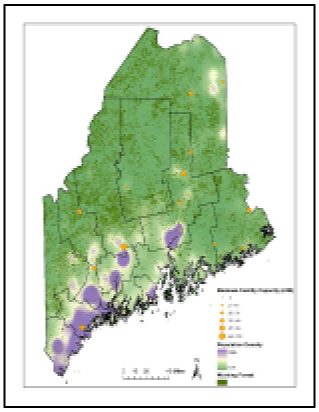

Figure 3.5 Biomass facilities in relationship to population centers and working forests (EIA 2008)

Sustainability of Wood to Energy Biomass

Wood biomass is comprised of woody material harvested from the forest for energy production, and includes residues produced during harvesting, fuelwood from forestlands, residues from processing mills, and woody material extracted for fire hazard reduction and forest health improvement initiatives (Perlack, Wright et al. 2005). This material is harvested simultaneously with the other trees in managed timberlands.

Wood-based energy has the potential to be completely renewable if managed in a sustainable way. If poorly managed or harvested, it can lead to diminished soil productivity, water quality, decreased biodiversity, and lower forest yields in the long term (Benjamin 2009). Maine's foresters have extensive experience with forest management, as the paper and timber industries have long been integral to Maine's economy and culture. Both state and national legislation promote Best Management Practices (BMPs) and other sustainable forestry practices to protect forest health and ensure sustained productivity (for more information, see "Laws and Institutions"). Best Management Practices are a series of forestry guidelines designed to minimize negative environmental impacts of logging; BMPs include erosion control measures, soil stabilization, and proper handling of hazardous material (MFS 2005). The risk of Maine's forests becoming significantly damaged is relatively low because of Maine's longstanding history with working forests and timber management and extraction (Benjamin, Lilieholm et al. 2009).

Responsible Forest Management

However, if Best Management Practices are not followed then forest health, including wildlife habitats, and long-term forest productivity could be jeopardized (Shepard 2006). The most invasive and potentially damaging aspect of the wood production process is resource extraction. Soil quality, water quality, and diversity are three main factors that, if compromised, could lead to decreased overall forest productivity (Benjamin 2009). Within the resource extraction process, soil productivity can be diminished if erosion prevention measures are not implemented. Water quality can be threatened by excessive forest floor disturbances, lack of control of water flow, or erosion control methods that are implemented too close to the water level in streams. Habitats can be disturbed by changing the composition of the forest by tree species, number, and density; reducing the number of decomposing down logs and standing dead trees; disruption from skidders and other large machinery; and the creation of roads, which can cause problems with runoff, soil compaction and habitat fragmentation.

One impact of increased wood harvesting that has the potential to harm forest ecology is nutrient depletion, which results from the removal of living biomass, including mineral nutrients, from the forest without proper supplementation (Ljung and Nordin 1997). This can lead to decreased forest productivity, thereby diminishing future potential for biomass resources.

A tree consists of five distinct components: roots, stem, bark, branches, and foliage. In tree harvesting, the roots are almost never taken from the forest. These contain a significant proportion of the tree's nutrients, so when they decompose, the nutrients are recycled back into the soil (Sendak, Brissette et al. 2003). Conventional stem-only harvesting is generally accepted as a sustainable practice for most forest sites and is not considered to have any long-term detrimental effects on site nutrient pools because of the small portion of nutrients extracted and the long rotation periods that allow for nutrient replenishment (Smith, McCormack et al. 1986). In fact, stems contain approximately 65% of total above-ground biomass, yet only 25% of above-ground nutrients, making them relatively nutrient-poor. However, the most dominant extraction method in Maine is whole-tree harvesting, potentially a cause for concern for long-term nutrient diminution (Benjamin 2009).

Conflicts of Values

Nearly all woody biomass consists of "waste wood," predominantly the branches and bark that are otherwise unmarketable wood, and "hogfuel," residues from sawmills and paper mills. This wood is of "pulpwood quality" or lower, which are the lowest quality wood products and were previously only used by the paper industry. The introduction and expansion of the wood-to-energy sector creates a new market for loggers, adding value to their harvest and utilizing that which was previously considered waste. This new market has economic benefits, but may also introduce conflicts of interest (Benjamin, Lilieholm et al. 2009).

For example, a standing dead tree has at least three conflicting values which must be balanced by loggers. First, standing trees provide habitat and thus help to protect biodiversity. Second, if chipped and put in skid trails a tree will reduce soil compaction and erosion from the machinery, helping to protect the overall forest health. Lastly, if chipped and sold to a bioenergy facility, a tree will generate income. Benjamin (2009) summarizes this conflict of values, and explains that tradeoffs are necessary when deciding on the use of a tree. Although regulations exist to deal with these tradeoffs with regard to the general forest industry, there are no specific guidelines outlined for woody biomass use. Essentially, wood biomass energy promises a new and economically beneficial use for low-grade wood, yet it introduces yet another option for its use, further complicating the decision-making process for forest management.

Biomass in the Wood Industry Context

Within the forest sector there are varying levels of wood quality, from the most expensive, veneer wood, to the least expensive, biomass wood chips (Wood-to-Energy Task Force 2008). The difference in quality is substantial enough that the wood used for wood biomass energy could not be used for anything else, with the possible exception of pulp for paper mills. Because loggers want to maximize their profits, the economics ensure that wood is used for different purposes depending on quality. In an ideal world where there are enough buyers of wood and contractors, the growth of the wood biomass energy sector would merely increase revenues for the wood industry, but the reality may not be so simple. Benjamin and Lilieholm et al. (2009) warn that the bioindustry may be forced to compete for services and materials with existing wood-using facilities.

Impact on Human and Ecological Health

Although biomass combustion generates pollutants, proper monitoring and control methods can help to limit health and environmental effects posed by these substances. The US Environmental Protection Agency (EPA) regulates and limits emissions of toxic substances under the Clean Air Act and the Clean Water Act, and allows biomass energy facilities to release limited amounts of pollutants if they have applied for and received a permit. Pollutants of particular concern to human health include particulate matter, heavy metals, ground-level ozone, and dioxin (van Loo and Koppejan 2007). The release of these substances may be minimized and partially or entirely contained through primary and/or secondary emissions reduction measures (see Table 3.5 for a discussion of chemical substances, potential health effects, and emission reduction and containment measures).

Table 3.5 Toxic substances generated from biomass burning, containment measures, and health effects (van Loo and Koppejan 2007; ATSDR 2010a; ATSDR 2010b; Khan, de Jong et al. 2010)

Substance	**Origin**	**Health effects if released**	**Emission reduction and containment measures**
Particulates	Consists of ash particles and fuel particles that have become airborne; may damage boilers and pose health threats if emitted	Carcinogenic to humans; can harm human respiratory system	Electrostatic precipitators (ESPs) and baghouse filters may reduce particulate emissions in commercial biomass facilities; other secondary measures may be used
Sulfur Oxides	Result from complete combustion of fuel sulfur	Can harm human respiratory system; contributes to asthma	Emissions may be reduced by lime or limestone injection; may by contained through secondary emission reduction measures
Carbon Monoxide	CO is generated during combustion, but can be minimized in commercial biomass burning applications because of high temperatures and low levels of excess air	Reduces oxygen intake; may be especially harmful to asthmatics. Indirect greenhouse gas (forms CO_2)	Some secondary containment measures may be applicable
Carbon dioxide	Results in combustion of all biomass fuels	Greenhouse gas	No practical containment methods
Volatile Organic Compounds	Generated during conversion of fuel carbon to CO_2 and fuel hydrogen to H_2O	Can harm human respiratory system	Some secondary containment measures may be applicable

Nitrogen Oxides	Generated during complete combustion of fuel nitrogen; formed during gas phase combustion and char combustion	Lung damage; particularly harmful to asthmatics and those with chronic obstructive pulmonary disorder	Amount generated may be reduced by minimizing nitrogen content in fuel and excess air and ensuring a high combustion temperature. May be contained through secondary emission reduction measures
Polycyclic Aromatic Hydrocarbons (PAHs)	Generated during conversion of fuel carbon to CO2 and fuel hydrogen to H_2O	Carcinogenic; can harm reproductive system; damage to skin and immune system (ATSDR 1995)	High combustion efficiency and certain additives to the fuel may be used to minimize the amount generated
Heavy metals	May be contained within virgin biomass fuel or result from contaminated fuel (such as treated or painted wood); housing and construction debris may hold high levels, which become vaporized upon combustion	Carcinogenic; may cause neurological damage; symptoms vary based on specific substances	Heavy metals may remain in ash, evaporate, or attach to the surface of particles generated during combustion; may be contained through secondary emission reduction measures

Pollution and Human Health

Large-scale biomass power has been criticized because of the toxic substances that are created during wood combustion (UCS 2010). For example, the American Lung Association (ALA 2010) acknowledges biomass as a sustainable fuel source in New England, but calls attention to perceived threats posed to the environment and human health through industrial biomass burning. The ALA position statement on biomass expresses concern about the effects of biomass emissions on vulnerable populations, such as people with asthma, chronic respiratory disease, or cardiovascular disease, and also calls attention to the diesel exhaust emitted by trucks used to transport wood to combustion facilities.

The statement also raises two specific regional concerns: the lack of legislation to protect those who may bear the brunt of a facility's pollution without gleaning the benefits, and inadequate air monitoring services. Maine, for example, has only eight air monitoring stations serving the whole state (DEP 2009).

Furthermore, biomass facilities which generate only electricity have an average efficiency level of 15-35%, which means that energy is only generated from 15-35% of the wood that is burned. If electricity and heat are co-generated, the efficiency level can reach 80-85% (Combined Heat and Power Partnership 2007; Peterson and Haase 2009). However, pollution is generated from 100% of the wood, even if only a portion of the released energy is harnessed (ALA 2009). Co-generation is preferable from a human and ecological health standpoint, because it generates a minimum of pollution per unit of energy.

Comparisons to Other Energy Sources

Table 3.6 compares the air emissions of common pollutants generated by various energy sources, and shows that wood biomass energy emits less carbon dioxide, sulfur dioxide, and nitrogen oxides than does fossil fuel combustion.

Table 3.6 Air emissions from various energy sources (EPA 2007)

Energy Source	**Carbon Dioxide**	**Sulfur Dioxide**	**Nitrogen Oxides**	**Other Notable Air Emissions**
Natural gas	1135 lbs/MWh	0.1 lbs/MWh	1.7 lbs/MWh	Methane may be emitted after incomplete combustion
Coal	2,249 lbs/MWh	13 lbs/MWh	6 lbs/MWh	Mining, cleaning, and transporting coal emits methane

Oil	1672 lbs/MWh	12 lbs/MWh	4 lbs/MWh	Oil wells and collection equipment release methane; processing equipment may run on diesel
Nuclear energy	None	None	None	Uranium mining associated with fossil fuel emissions
Municipal Solid Waste	None[1]	0.8 lbs/MWh	5.4 lbs/MWh	Emissions vary based on waste fuel; may release high levels of toxic pollutants, such as mercury and dioxins
Hydroelectricity	None	None	None	Vegetation decay in lake may release methane
Solar	None	None	None	None
Geothermal	None	None	None	None
Wind	None	None	None	None
Biomass	None[1]	Small amounts, depending on fuel source	Small amounts, depending on fuel source	[see table 3.5]

The burning of biomass for energy holds considerable advantages over fossil fuel-based energy sources such as coal and oil because of its minimal carbon emissions. Both biomass and solid waste combustion are generally accepted as carbon-neutral despite the carbon that they emit, because this carbon release is considered to be part of the environment's natural carbon cycle. Woody biomass burning will result in a net increase in atmospheric carbon unless an adequate amount of trees are regrown to capture the carbon that was released; for this reason, the carbon neutrality of wood biomass energy is under continued debate (see "Carbon Dioxide Emissions").

Solar, static geothermal, and wind energy are carbon-neutral and also do not emit sulfur dioxides or nitrogen oxides (EPA 2007). However, the extent of their use in Maine is currently limited in comparison to other energy sources.

Table 3.7 Liquid and solid waste from various energy sources (EPA 2007; EPA 2010).

Energy Source	**Water Discharge**	**Solid Waste Generation**
Natural gas	Releases chemical and thermal pollution; requires permit by EPA	None
Coal	Water pollution includes heavy metals from mining and plant runoff; requires permit by EPA	Ash content averages 10%; primary components are metal oxides and alkali; most ash waste disposed of in landfills and abandoned mines
Oil	Releases chemical and thermal pollution; may contaminate groundwater; risk of oil spills	Refining process generates wastewater sludge with high levels of toxic substances; solid waste may accumulate in burners at power plants
Nuclear energy	Releases heavy metals, salts, and traces of radioactive uranium; may contaminate ground- and surface water	"Spent" uranium fuel disposed of as toxic waste; total US production of spent uranium averages 2,000 metric tons/year; waste stored on-site at nuclear plants
Municipal Solid Waste	Releases chemical and thermal pollution; requires permit by EPA	Combustion generates ash, whose composition varies depending on fuel source; disposed of in landfills; may contain toxic substances

Hydroelectricity	None	None
Solar	None	Very small amounts of toxic materials results from production of photovoltaic wafers
Geothermal	Possible groundwater contamination, but may be contained with proper management	None
Wind	None	None
Biomass	Releases chemical and thermal pollution; requires permit by EPA. Biomass crops may use pesticides.	Generates ash; toxic substances are present, but levels are low in relation to other energy-production-based solid waste

Ash as a Nutrient Supplement

When wood biomass is burned, approximately 10% of the total fuel mass remains as solid waste in the form of ash. Wood biomass ash contains heavy metals and other toxic substances that may cause harm to the environment and human health if indiscriminately released; the ash must be handled carefully to avoid releasing toxic pollutants that might otherwise have been containable (Ljung and Nordin 1997). Although biomass ash is often treated as a hazardous waste, such disposal fails to take advantage of the beneficial components of ash, such as valuable nutrients. Because these nutrients are vital to long-term forest health, biomass ash holds promise as a soil supplement for harvested forests.

Because trees contain nutrients, removing large quantities of trees from a forest without replacing the lost nutrients results in long-term degradation to forest health (Smith and McCormack 1986). Typically, ground limestone is used to supplement needed nutrients, but wood ash contains these same nutrients and more. Therefore wood ash may be a viable option that could be used to maintain the health of harvested forests in Maine (Table 3.8). However, if ash is used as a nutrient supplement, separation techniques can and should be used to minimize the return or introduction of such toxic substances into the environment (Ljung and Nordin 1997).

Table 3.8 Substances in wood ash and ground limestone (Wright 2009)

Element	**Wood ash concentration (%)**	**Ground limestone concentration (%)**
Calcium	15.00	31.00
Potassium	2.60	0.13
Aluminum	1.60	0.25
Magnesium	1.00	5.10
Iron	0.84	0.29
Phosphorus	0.53	0.06
Manganese	0.41	0.05
Sodium	0.19	0.07
Nitrogen	0.15	0.01

Carbon Dioxide Emissions

Proponents tout wood biomass energy power as a carbon neutral energy source. This claim is based on the positive effect of forest thinning on the forest's rate of carbon sequestration. When forests reach maturity, the overall growth rate of the forest biomass slows. Thinning facilitates young saplings' growth, allowing carbon to be sequestered at a higher rate and offsetting the emissions from combustion. Thus, carbon harvested from forests may be completely replaced in the long-term (Marland and Marland 1992).

However, the carbon neutrality of wood biomass energy relies on two assumptions: First, forests must be sustainably managed so long term carbon sequestration levels remain constant.

Second, the process of turning woody biomass heat to and electricity consumes no fossil energy.

Maine's forest history suggests that this first assumption holds true. Long term afforestation trends since the mid 1800s and a relatively constant level of total forest biomass over the past 20 years suggests that Maine's forests are indeed being managed sustainably on the medium term

(Laustsen 2009). Furthermore, Maine laws and regulations promote sustainable forestry practices. This indicates that long-term carbon emissions resulting directly from the combustion of woody biomass can be discounted to zero.

Nonetheless, the long-term sustainability of Maine's forestry practices has not been tested, and relies on the retention of nutrients as stated above. This is critical to carbon neutrality since re-sequestration occurs over decades of regrowth. Marland and Marland (1992) find that over short time spans, forest preservation will yield higher net benefits than harvesting biomass to offset fossil energy. The time period for harvesting to outweigh preservation is lower for forests that are actively harvested and lands with higher productivity (Schlamadinger and Marland 1995, Baral and Guha 2004).

Additionally, the harvesting, transportation, and processing of woody biomass clearly require fossil energy. Logging equipment, chipping equipment, trucking, and certain biomass boiler systems all require secondary fuel sources. Thus, total carbon emissions of wood biomass energy depend on the transportation distance, forestry practices, and processing and combustion infrastructure. An independent report commissioned by the pellet fuels industry, Katers and Kaurich (2007) estimate that for every 1 million BTUs of heat produced by biomass chips 47,000-114,000 BTUs of fossil fuels must be burned (see Fig 3.6 and Table 3.7). Spath and Mann (2004), and Timmons and Mejia (2010) estimate similar results with 93,000 and 32,000 BTUs of fossil energy per million BTUs of heat produced, respectively. Using Katers and Kaurich's estimates, the lifecycle carbon emissions of wood biomass energy are 9-21 times less than those of distillate fuel oil.

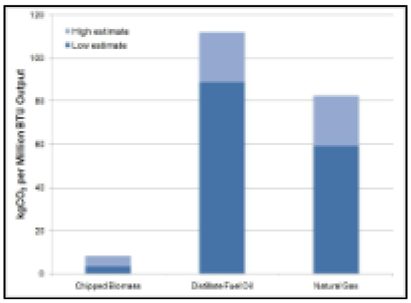

Figure 3.6 Lifecycle carbon emissions estimates of selected heating fuels (Katers and Kaurich 2007, EIA 2010c)

Table 3.9 Estimated life cycle emissions of selected heating fuels (Katers and Kaurich 2007)

Fuel	**BTUs of fossil energy per million BTU output**	**$kgCO_2$ per million BTU output[1]**
Chipped Biomass	47,437 - 113,909	3.47 - 8.33
Distillate Fuel Oil	1,215,243 - 1,529,599	88.89 - 111.89
Natural Gas	1,117,437 - 1,554,067	59.29 - 82.46

[1] Fossil energy emissions from biomass and oil assumed to be from diesel sources, natural gas emissions assumed to be from natural gas. Carbon density conversion factors from (EIA 2010).

Wood Biomass Development Potential

Despite the relative advantages of wood biomass energy, its widespread adoption is dependent on the availability of wood fuelstock and its economic competitiveness.

Maine's Forest Resources

Maine's unique position as the state with the highest percentage of timberland, paired with its 200-year history of logging and other forest product industries, situates Maine well to engage in sustainable biomass production (MFS 2005). Eighty-six percent of Maine's 19.9 million acres is classified by the USDA Forest Service as timberland (MFS 2008). Ten and a half million acres of the Unorganized Territory remain largely undeveloped forestland, most of which is actively managed for timber production (MFS 2005). Less than 5% of the forest is harvested annual by clear-cutting, which is a very low percentage compared to most other states (MFS 2005). Further, extraction of forest products has stabilized in the last two decades, indicating that sustainable yields have been achieved and that extraction is not limitless, nor is it viewed as such (MFS 2005).

Although annual harvest tonnage has remained relatively constant over the past 20 years, a 2008 study by the Maine Forest Service concludes that forest biomass output can be sustainably increased. In 2008, 3.26 million green tons (virgin wood, complete with moisture content) of biomass chips and 513,000 green tons of hogfuel originated from Maine forests (MFS 2008). With minor improvements in utilization and forest practices, an estimated 3.8 million green tons could be harvested from tops, limbs, and previously unmerchantable whole trees, and an additional

1.47 million tons could be harvested through thinning of overstocked stands (Table 3.10). Total additional biomass chip output is estimated at 5.86 million tons, excluding imports. This implies that availability of forest output will not be a limiting factor in wood biomass energy development.

Table 3.10 Additional available biomass (adapted from MFS 2008)

Source	**Tons**
Improved harvesting and utilization from currently harvested stands	3.8
Harvest in overstocked stands not previously considered commercially viable	1.47
Increasing productivity through more intensive management	0.61
Addition imports	3.83
Total	**9.69**

Economic Competitiveness of Wood Biomass Energy

The economic feasibility of biomass power depends on the marginal cost of biomass power relative to other energy sources. At $2.91 per million BTU (MMBTU) in 2008, the delivered cost of biomass is less than both residual fuel oil, at $12.24/MMBTU, and gas, at $11.61/MMBTU (Fig 3.7). As such, chipped biomass is competitive with all primary energy sources in Maine. Furthermore, the large difference in price indicates that biomass energy will remain competitive despite volatility in prices.

Since the long-term costs of wood biomass energy are much lower than oil and gas, the major barriers to conversion to wood energy are in start-up or conversion costs. This suggests that promotion of wood biomass energy can be easily achieved by providing low interest loans to plant operators.

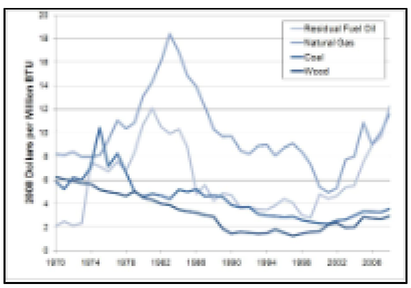

Figure 3.7 Primary industrial fuel prices in Maine over time (EIA 2010a)

Case Study: Biomass Facility at Colby College

Colby College, located in Waterville, ME, has committed to achieving carbon neutrality by 2015 (CCAP 2010). As reported in the 2010 Colby Climate Action Plan (CCAP), 70 percent of the college's total carbon emissions were from heating. The CCAP introduces specific actions to reduce and mitigate these emissions, one of which involves the construction of a biomass facility. This $11 million facility, to be completed by January of 2012, has been approved by the Board of Trustees and construction has commenced (Terp 2010).

The biomass facility will be comprised of two Chip Tech 400 HP boilers that be fueled by waste wood chips, or "hog fuel" (Murphy 2010). The new facility would fulfill 90 percent of the campus' steam demand, replacing the use of the current steam plant, which uses # 6 residual oil, during all but the coldest days of the year (CCAP 2010). The college currently consumes over 1 million gallons of residual fuel oil, about 2-3 truckloads per day (Murphy 2010). After the biomass facility is on-line, the Colby Physical Plant Department (PPD) predicts that the campus will use about 22,000 tons of wood chips per year, or 3-4 truckloads per day in peak season. The wood source for this project has not yet been determined, though Colby's PPD plans to source all the wood within a 50 mile radius from campus (Libby 2010). Further, they will only purchase wood residues, and hope to source from certified logging initiatives. The College's current steam plant includes a turbine that co-generates electricity from the steam produced in the boilers, and this turbine will continue to function with the transition to biomass energy, allowing for co-generation of heat and electricity and thus improving the facility's over all efficiency.

The predicted payback is 6-9 years, depending on fuel oil and biomass chip cost fluctuations (Murphy 2010). A grant from the Efficiency Maine Trust will further aid in the financing of the project (see Laws and Institutions).

Potential Scenarios

The current state of biomass in Maine reveals several directions the state can take in its use of biomass energy. We provide three potential future scenarios:

Smart Development

After realizing the potential that biomass energy has to offer the state in terms of economic development, energy independency, and environmental protection, Maine's government offers additional tax credits or other economic incentives to encourage and facilitate the use of biomass and other renewable energy sources in Maine on a large scale. As a result, Maine takes full advantage of its abundant natural resource, so that within several decades biomass is adopted as the state's primary energy source. As such, Maine leads the way among US states to energy independence. The state uses local forest resources and existing industrial facilities, and engages in responsible forestry by supplementing the soil with nutrients and allowing sufficient regrowth to ensure sustainable harvests.

Hasty Development

As the vast availability of Maine's resources is recognized and taken advantage of, the state's biomass industry develops rapidly into the leading energy supplier. Although Maine becomes more energy independent, weak regulation provides an incentive for industry to cut corners in ecological and industrial planning in order to continue producing energy and gain maximum profit. As a result, best forestry practices and pollution controls are not implemented. Poorly planned forestry schemes fail to allow for sufficient regrowth of the forests that are cut for biomass energy, partially negating the carbon-neutral ideals of biomass energy by failing to contain all the carbon that is released through combustion. Forest soil is not supplemented with nutrients as biomass is removed from the ecosystem, leading to long term reduction in forest health and productivity. Other ecosystem services, including water filtration and habitat for biodiversity, are ignored.

Furthermore, pollution controls are unenforced, so that toxic gases and particulates are released into the air, causing health effects and lung damage among vulnerable individuals in the communities that neighbor wood biomass energy facilities. Heated water that is released into waterways adjacent to power plants leads to thermal pollution, harming Maine's fragile and valuable aquatic ecosystems. Although biomass is a viable and beneficial option, its adoption without proper planning and precautions could lead the energy source to be ultimately unsustainable.

No New Development

In the future, Maine retains its current status quo, with biomass providing approximately 35% of the state's energy needs. Maine continues to rely heavily on petroleum, gas, coal, and to a limited extent, hydropower. Oil prices continue to fluctuate, causing financial uncertainty and at times contributing to economic stress as Maine residents face high volatility in fuel prices. In the long term, as fossil fuels are depleted and energy prices rise, Maine struggles to meet its energy needs---while the state's forest resources remain untapped.

Conclusion

Maine is in a unique position to pursue large-scale wood biomass energy initiatives. With 86% of state land area classified as timberland, Maine's long forestry tradition and abundant forest resources have the potential to provide extensive fuel for biomass combustion. Biomass benefits Maine's economy. In the long term, biomass provides cheaper energy than fossil fuels, and conversion of existing facilities will return money currently spent on imported fossil fuels to Maine's core forestry sector.

Moreover, the scale of biomass currently dwarfs other renewable energy sources. Providing 35% of Maine's energy consumption, biomass has immediate potential for large-scale carbon emissions reduction. Current state laws promoting renewable energy adoption such as Maine's Renewables Portfolio Standard further encourage its adoption.

Nonetheless, Maine's forests are multi-use resources that hold important values in terms of wildlife habitat, biodiversity, recreation, and watershed protection, in addition to woody biomass production. Increased intensity of extraction from biomass threatens these aspects of forest ecology. Ecologically responsible forest management and nutrient supplementation can help mitigate these threats.

Finally, biomass is favorable over fossil fuels in terms of price, the reduction of carbon emissions and the preservation of public health. Life cycle analyses estimate that biomass energy emits 9-21 times less life-cycle carbon emissions than do fossil energy sources. Although burning woody biomass results in the creation of toxic substances, these substances can be largely contained through proper industrial methods and controls, and their release into the environment is limited under federal law. More importantly, biomass combustion results in the release of fewer toxic substances than does the combustion of fossil fuels, which are the energy sources most likely to be replaced by biomass. Although certain sources of renewable energy, such as wind and solar, are indeed cleaner than biomass, they currently provide only a very small percentage of Maine's energy, and may be less viable in the short term.

Considering economic, ecological, and health concerns, wood biomass energy shows significant promise as a sustainable energy source for the state of Maine.

Recommendations

In order to reduce Maine's carbon footprint, reduce pollution relative to levels emitted by fossil fuels, and stimulate the local economy, Maine should continue to support the conversion of fossil fuel generators to wood biomass energy through proactive policy measures. In addition to current economic incentives, this can be facilitated through financing options such as low interest loans to reduce the barrier of high investment costs. Such loans could benefit the state financially in the long run, returning money currently spent on foreign oil to its core forestry sector.

Additionally, Maine should continue to ensure that Best Management Practices for forestry are followed in terms of habitat protection, erosion prevention, and in particular, long-term nutrient retention. Healthy forests are central to Maine's environment, economy, and energy needs. They are multi-use resources valued for wildlife, biodiversity, recreation, and watershed protection. Maine should continue to monitor the health of its forests to ensure that efforts to meet energy needs do not compromise theses values. If forest health begins to decline, stricter measures should be implemented. With growing biomass demands, woodlot owners should also be cognizant of the rate at which nutrients are removed and supplement when necessary.

Although biomass emits less pollution than do fossil fuels, pollution controls should be implemented and enforced, requiring that emissions fall under safe levels as defined by the Clean Air Act and Clean Water Act. Permits should continue to be required of biomass facilities by the national government. In order to encourage compliance, fines should be imposed if permit agreements are broken.

Finally, because biomass boilers are more efficient when co-generating both heat and electricity, policy measures should focus on these applications first.

Appendix

Appendix 3a. Land and water resource use by various energy sources (EPA 2008)

Energy Source	Land Resource Use	Water Resource Use
Natural gas	Natural gas extraction may destroy wildlife habitat; impacts include erosion and loss of soil productivity	Minimal water required for cooling purposes
Coal	Soil at power plants may be polluted; coal mining, especially surface mining, requires access to large amounts of land	Large amounts of water required at mine site, as well as during combustion for steam production and cooling purposes
Oil	Waste from refining and power plants may contaminate ecosystems; oil spills, when they occur, pose a serious threat to marine and coastal ecosystems	Large amounts of water required during combustion for steam production and cooling purposes; oil drilling and refineries reliant on water for industrial processes
Nuclear energy	Greatest concern is the storage of toxic and radioactive byproducts of energy production	Large amounts of water required for steam production and cooling
Municipal Solid Waste	Land required for power plants; ash is disposed of in landfills	Water-to-energy ratio is similar to that of fossil fuel-based plants; however, municipal solid waste facilities tend to be smaller, and thus use proportionately less water
Hydroelectricity	Dams may impact large areas of land along rivers, destroy wildlife habitat, and lead to erosion along the riverbed	Requires large amounts of flowing water for dams; can have a strong effect on the river's ecosystem and on the ability of humans and wildlife to utilize the river's resources
Solar	Photovoltaic solar panels require minimal land when sited on preexisting structures; solar-thermal technology may require large amounts of land	None for electricity generation; water may be used to create steam
Geothermal	Moderate land required for power plants; if water is not re-injected, land surface may sink	Moderate water use; most of the water is later re-injected into wells

Wind	Require land, but the land may still be used for other purposes (eg farming); wind farms may raise aesthetic concerns	Minimal water required to clean turbine blades; not needed in areas with adequate rainfall
Biomass	Power plants require land use; large areas of land required for biomass growth, which may deplete the soil of nutrients; however, biomass growth areas may provide temporary wildlife habitat and recreational opportunities	Moderate water use; required for steam production and cooling; some of the water may be re-used, reducing the overall demand

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