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Forest Biomass Energy Policy in the Maritime Provinces:
Accounting for Science

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About ECELAW

East Coast Environmental Law (ECELAW) is a public interest environmental charity established in 2007. From our offices in Halifax, ECELAW advocates for the fair application of innovative and effective environmental laws in Atlantic Canada. For more information, please visit www.ecelaw.ca.

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Executive Summary

The demand for forest biomass energy is increasing both in the Maritimes and globally, and is driven almost exclusively by government policies and incentives to enable renewable energy generally and, in some cases, biomass energy specifically. The extra costs required to enable biomass energy are justified, in part, on an assumption that biomass energy reduces net carbon emissions to the atmosphere, thereby helping to meet climate-change mitigation goals.

The assumption that net carbon emissions are reduced by generating electricity by burning forest biomass, however, is being challenged. While the simple “burn a tree, grow a tree” formula may seem intuitively sound, research is showing that in many cases, cutting and burning trees for electricity actually increases net carbon emissions for at least several decades, and sometimes for over a century. Most government policies on biomass energy, to date, have not accounted for changes to forest structure, changes to forest productivity, impacts of multiple biomass harvests, varying efficiencies of the different methods of converting biomass to energy, and time-lags in carbon reabsorption by forests.

Furthermore, certain types of forest biomass harvesting have been shown to have negative impacts on forest biodiversity, beyond the impacts from more traditional forms of forest cutting. These impacts include reduced abundances and reduced and/or changed diversity of forest amphibians, birds, insects, and soil organisms. The negative impacts of biomass harvesting on biodiversity are related to reduced coarse woody debris and standing deadwood habitat, increased environmental stresses such as higher summer air temperatures and moisture loss, and changes to soil nutrients and acidity. Biomass harvesting has also been shown to reduce forest productivity in some sites.

To date, governments have been slow to respond to the scientific evidence on the impacts of harvesting and burning biomass for electricity on carbon emissions and biodiversity. However, some bright spots are emerging. The state of Massachusetts has introduced requirements, such as minimum efficiencies, that biomass energy producers must meet before qualifying for government incentives. The European Union has also introduced new guidelines on biomass energy production to recognize and draw attention to the negative consequences of some forms of biomass energy.

On the basis of the information available, as detailed in this report, the East Coast Environmental Law Association strongly recommends the provincial governments in the Maritimes, particularly Nova Scotia and New Brunswick, to change their renewable energy policies regarding forest biomass energy to bring them in line with current scientific understanding of the impacts of biomass energy. Specifically, ECELAW recommends that the Maritime governments introduce minimum efficiencies for biomass energy to be considered renewable energy (such as 60 percent, as in Massachusetts). ECELAW recognizes that a 60 percent minimum efficiency would effectively shift the focus on biomass energy away from electricity generation and towards heating buildings. ECELAW further recommends that the Maritime Provinces introduce biomass harvesting regulations, applicable to both Crown and private lands, to ensure that biomass harvesting maintains sufficient standing and fallen deadwood, forest structure, and soil quality so as not to cause significant negative impacts on forest biodiversity.

PART I: Introduction

1. Introduction to Forest Biomass Energy

Both within the Maritimes and globally, demand for biomass energy is increasing, driven almost entirely by policy decisions to encourage non-fossil fuel energy sources,[1] and biomass energy specifically.[2] Annual global biomass energy production is predicted to increase at an annual rate of 0.6-2.3% until at least 2030.[3] Renewable energy was estimated to be 19% of global energy production in 2012, with 9% of this coming from traditional biomass use (i.e., for traditional cooking and heating). Electricity production from biomass still accounts for a relatively small amount of total global energy production, at an estimated 1.8%.[4] Electricity from wind power, for comparison, accounts for an estimated 2.9% of global electricity production.[5]

In Nova Scotia, electricity produced from forest biomass fuel increased several-fold with the 2013 addition of Nova Scotia Power Inc.'s (NSPI) 60 megawatt (MW) biomass power plant in Port Hawkesbury. Combined with NSPI's recently acquired 30 MW biomass energy facility in Brooklyn (purchased in 2013 from the Nova Scotia government, which had acquired it from the former Bowater-Mersey Paper Company in 2012), the 90MW of forest biomass-to-electricity capacity produces approximately 4% of Nova Scotia's electricity.

New Brunswick has four electricity-generating biomass facilities, with a total capacity of 159.6 MW (Twin Rivers Paper 87 MW; Irving Pulp & Paper 30MW; AV Cell Inc. 17.6MW; AV Nackawic 25MW).[6] A 2012 report from the K.C. Irving Chair in Sustainability at the Université de Moncton claims that New Brunswick has the potential of 463 MW of electrical capacity by burning 15.5 million green tonnes of harvested wood annually.[7] In 2010, the New Brunswick government issued tenders for the harvest of approximately 1.3 million tonnes of wood to be used for biomass energy.

Prince Edward Island has a small (1.2MW) electricity generating facility that burns a combination of waste wood and oil, but does not currently have forest biomass electricity capacity.[8]

Driving forces behind policies to increase forest biomass energy include presumed carbon emission reductions, reducing reliance on foreign fossil fuels (i.e. energy security), job creation, rural development, additional forest harvesting opportunities, and reduced energy costs for forestry businesses and forest product manufacturers.[9] The driver among these forces from an economic feasibility perspective is the presumed reduction in carbon emissions that forest biomass energy offers. Once defined as a renewable energy source, forest biomass energy producers are entitled to government incentives that make forest biomass energy economically feasible.

Biomass energy is also regarded favourably by power utilities, relative, to wind energy, because it can provide base-load power. That is, biomass energy can be counted on as a predictable amount of energy at any given time. However, because biomass electricity is more expensive than fossil fuel-based electricity (and, in some cases, wind-based electricity), it would not be developed by power utilities or other private energy providers in most situations without the incentives provided under various renewable energy promotion policies.

Government policies that encourage biomass energy are generally predicated on two assumptions: first, that biomass energy is environmentally friendly because the fuel source is renewable and can be sustainably managed; and second, that biomass energy reduces overall carbon emissions into the atmosphere. Scientists and policy analysts, however, are starting to question both of these assumptions. For example, for the first time since its inception in 2004, the United Nations' Renewable Energy Network called attention to biomass energy sustainability and carbon neutrality questions in its 2014 annual report on global renewable energy trends.[10]

The purpose of this report is to evaluate whether government policies that promote forest biomass energy are justified by the available evidence on the biodiversity and carbon emission impacts of forest biomass harvesting and burning. That is, we evaluate whether government policy on forest biomass in the Maritimes is keeping pace with science. Is the harvest of forest biomass sustainable from a biodiversity perspective and does the burning of forest biomass reduce overall carbon emissions? If not, then should governments continue to offer incentives to make forest biomass energy economically feasible?

What is Forest Biomass?

Biologically defined, forest biomass is all living or dead material in the forest ecosystem. As a harvested product, forest biomass is generally considered to be wood of low economic value from living or recently dead trees and shrubs, including tops, branches, foliage, stumps and roots, as well as dead trees with sufficient structural integrity to survive transport. In practice, the parts of trees and shrubs utilized as biomass product is influenced by government regulations and by harvesting costs. The province of New Brunswick restricts biomass harvesting to the above-ground portion of trees and shrubs that are otherwise non-merchantable. The province of Nova Scotia issued a draft directive in 2013 that restricted biomass harvested from Crown land for renewable energy projects to stem-wood only (i.e., that whole-tree harvesting on Crown land not be permitted for biomass to be used as renewable energy). Biomass fuel may also be milling residues (e.g. sawdust, bark and slab wood) and lumber wastes from construction.

PART II: Biomass Energy Policy

2. Biomass Energy Policy: International and European Union

At an international policy level, forest biomass energy is still largely considered to be carbon neutral. The Intergovernmental Panel on Climate Change (IPCC, which falls under the United Nations Framework Convention on Climate Change) established guidelines in 1996 that state that CO2 emissions from biomass burning “should not be included in national CO2 emissions from fuel combustion. If energy use from utilizing biomass from forests, or any other factor, is causing a long-term decline in the total carbon embodied in standing biomass (e.g. forests), this net release of carbon should be evident in the calculation of CO2 emissions described in the Land Use, Land-use Change and Forestry (LULUCF) chapter.”[11]

This position has been reiterated in subsequent publications of the IPCC. From a 2000 report, for example, the IPCC states that “biomass energy can be used to avoid greenhouse gas emissions from fossil fuels by providing equivalent energy services: electricity, transportation fuels and heat. The avoided fossil fuel CO2 emissions of a biomass energy system are equal to the fossil fuels substituted by biomass energy services minus the fossil fuels used in the biomass energy system.”[12] In a 2007 report, the IPCC recognized that forest management does influence the mitigation benefit of forests, but stopped short of addressing the basic assumption that biomass fuels are carbon-neutral: “For the purposes of this discussion, the options available to reduce emissions … [include] increasing the use of biomass-derived energy to substitute fossil fuels.”[13]

Other international institutions echo this view. The European Union’s 2006 Forest Action Plan[14] (yet to be updated) states that “more than half of the EU’s renewable energy already comes from biomass, 80% of which is wood biomass. Wood can play an important role as a provider of biomass energy to offset fossil fuel emissions….” The Commission of European Communities, responding to the EU Forest Action Plan, supports the use of forest biomass for energy generation: “Using wood as an energy source can help to mitigate climate change by substituting fossil fuel…. The Member States will assess the availability of wood and wood residues and the feasibility of using them for energy production at national and regional levels, in order to consider further actions in support of the use of wood for energy generation.”[15]

Similarly, the International Energy Agency (IEA) described forest biomass as “close to carbon neutral in most instances” in a 2007 report.[16] The IEA reiterated this view in a 2009 report, stating “bioenergy is already making a substantial contribution to meeting global energy demand. This contribution can be expanded very significantly in the future, providing greenhouse gas savings and other environmental benefits….”[17] The report concludes that bioenergy could contribute between a quarter and a third of the global primary energy supply in 2050.

3. Biomass Energy Policy: Nova Scotia

3.1 COMFIT and Renewable Energy Regulations

Numerous national and regional governments have enacted policies to foster development of renewable energy production, including biomass energy. According to the Renewable Energy Network (REN21), renewable energy targets have been enacted in 144 countries as of early 2014, up from 109 countries as of 2010.[18] Of these countries, 138 have policies in place to support renewable energy projects. Most of the renewable energy targets fall within the range of 0.2 to 1.5% annual increases in renewable energy production. Several mechanisms have been developed to facilitate attaining these targets. With respect to renewable electricity production, the most popular mechanism is known as a "feed-in tariff." Feed-in tariffs have been implemented in some 65 countries and 27 states/provinces as of early 2012, and are, essentially, guaranteed prices for electricity from renewable sources. The prices vary by renewable energy source to reflect the different production costs for different technologies.

The province of Nova Scotia has introduced both renewable energy targets and a feed-in tariff program. Under its 2010 *Renewable Electricity Regulations*, Nova Scotia is committed to obtaining 25% of its energy from renewable energy sources by 2015, and 40% by 2020.[19] Listed renewable energy sources include biomass that has been "harvested in a sustainable manner."[20] Nova Scotia's feed-in tariff program, known as the Community Feed-in Tariff program (COMFIT), is also described under the *Renewable Electricity Regulations*, and included a guaranteed tariff for electricity generated from combined heat and power (CHP) biomass facilities.[21]

The purpose of Nova Scotia's COMFIT program included offsetting the use of fossil fuels with clean energy, thus reducing greenhouse gas emissions from conventional fossil fuel systems. COMFIT was intended to be community-based, and was generally restricted to communities, co-ops, universities, First Nations councils and not-for-profit organizations; however, an exception was allowed for proponents of biomass projects to be any entity including a corporation.[22] Relative to other renewable energy sources, biomass has been determined to be more expensive than "large-scale" wind power projects (i.e., >50 kW) and run-of-the-river hydroelectric projects, thus was awarded a higher rate under the COMFIT program: 17.5 cents per kWh versus 13.1 cents and 14 cents per kWh, respectively. By early 2015, several biomass projects had been proposed and accepted under the COMFIT program, but were yet to be completed.[23] In August 2015, the Nova Scotia Government discontinued the COMFIT program, arguing that the program's expense outweighed its benefits.[24]

Nova Scotia's Department of Energy, in its 2009 Energy Strategy, cautioned that biomass energy needs to be evaluated in terms of the reliability, sustainability and cost of fuel supply.[25] However, the Department also viewed biomass energy as a positive development for its ability to supply firm, predictable amounts of electricity, and forecasted that some of the government's Renewable Energy Standard targets would be met with electricity from biomass facilities.

3.2 Biomass Harvesting Regulations

Nova Scotia has a high proportion of privately owned land relative to the rest of Canada. Twenty-nine percent of Nova Scotia is provincial Crown land, while 68% is privately owned (50% small private holdings and 18% industrial holdings). The upshot of this ownership pattern is that biomass harvesting regulations must apply to private as well as Crown lands to be effective throughout the province.

In 2008, the Nova Scotia government commissioned an independent panel to develop recommendations on natural resources management to feed into the Department of Natural Resources' ten-year planning strategy. The panel released its report in 2010, titled *A Natural Balance: Working Towards Nova Scotia's Natural Resources Strategy*. With respect to biomass energy, the Panel advised the government to "exercise great caution in the use of biomass for power generation," and urged the use of other methods of generating sustainable power.[26] The Panel also noted that "current regulations and compliance are not adequate to protect our resources," and that "there is ample evidence that our forests are already under considerable stress."[27]

The Department of Natural Resources released its strategy document in late 2010, which committed the Department, among other requirements, to reduce clearcutting, establish rules for whole-tree harvesting, and "clarify the use of forest biomass for energy," among other actions.[28] To date, the Department does not appear to have acted on any of these three commitments.

Nova Scotia's Department of Natural Resources has yet to develop biomass harvesting regulations. The existing regulation pertaining to biodiversity conservation during forest cutting, which applies to forestry operations on both Crown and private lands, is limited to ensuring that small clumps of trees are left during clearcutting operations (10 trees per hectare cut), and ensuring that forested buffers are left along watercourses.[29] The regulation also requires forest managers to leave behind natural levels of standing and fallen dead trees to provide for wildlife habitat and soil health, but this aspect of the regulation has yet to be applied or enforced to the best of ECELAW's knowledge.

Figure 1. Forest clumps left during clearcutting for biomass, in compliance with Nova Scotia's Wildlife Habitat and Watercourse Protection Regulations

The listed purposes under Nova Scotia's *Forests Act* include "developing a healthier, more productive forest capable of yielding increased volumes of high quality products," and "maintaining or enhancing wildlife and wildlife habitats, water quality, recreational opportunities and associated resources of the forest."[30] Nova Scotia's *Crown Lands Act* includes the objectives of enhancing productivity on Crown lands and increasing harvests of better-quality forest products, as well as providing for the maintenance of long-term productivity, diversity and stability of the forest ecosystem.[31]

While the Department of Natural Resources has not yet acted to regulate biomass harvesting, Nova Scotia's Department of Energy, in 2010, set a cap of 350,000 dry tonnes in 2011 (roughly equivalent to 700,000 green tonnes) of additional (new) forest harvest of standing trees per year for biomass electricity that would qualify as renewable under the *Renewable Electricity Regulations*.[32]

These regulations also stipulate that forest bioenergy projects must include a biomass fuel procurement plan that outlines how the proponent intends to ensure its fuel supply will meet sustainable harvesting requirements.[33] The regulations also limit energy production from biomass co-firing (that is, mixing biomass with coal in a coal-fired facility) to 150 GWh or less for the purpose of meeting the 2015 25% renewable energy target.[34]

3.3 NSPI Point Tupper Biomass Energy Facility

The most significant impact of the renewable energy designation for biomass electricity in Nova Scotia to date is the development of a 60 MW biomass facility by Nova Scotia Power Incorporated (NSPI, a subsidiary of Emera Incorporated). The facility is estimated to consume some 705,000 tonnes of woody biomass annually, as purchased, at least 385,000 tonnes of which is expected to come from forest harvesting, and the remainder from various mill residue sources.[35] The actual volume burned will vary according to moisture content of the fuel (wetter fuel necessitates burning more material), and the volume sourced from the forest will vary according to the available supply of mill residues. NSPI reported that they burned 393,423 green tonnes of biomass in 2014 (approximately 50 truckloads of wood per day), approximately three-quarters of which was sourced from within Nova Scotia, and one-quarter was imported from outside the province.[36] It is not clear why the facility burned less biomass than estimated, but may be a result of difficulties in securing a reliable supply of biomass.

Following a hearing in 2010, the Nova Scotia Utility and Review Board (NSUARB), which regulates NSPI, ruled that NSPI was justified in proceeding with the $208.6 million capital investment to undertake the project (NSPI required permission from the Board to undertake the capital investment, which would result in the cost being passed on to Nova Scotia rate payers).[37] Part of the hearing focused on whether wind energy would be a lower-cost, thus preferable, renewable energy source. The Board did not make a finding on the relative costs of the wind energy alternative and the proposed biomass project. Instead, the Board accepted NSPI's argument that the biomass project was preferable to additional wind energy projects on the basis that it would diversify a renewable portfolio based almost exclusively on wind, adding reliability and stability to the province's electricity generating system.[38]

In the course of the hearing, NSPI acknowledged that it would not have pursued the biomass project but for Nova Scotia's legislated renewable energy targets. As well, the Board found that NSPI would not have been willing to proceed with the project absent Board approval, that is, absent the risk-protection provided by obtaining Board approval for a capital investment, as opposed to the risk inherent in pursuing a power purchasing agreement with an independent supplier.[39] NSPI has not shown such hesitation in pursuing agreements with wind energy producers. While it is beyond the scope of this report to discuss business decisions regarding biomass projects, it is of interest to note the degree of aversion shown by NSPI to biomass projects that are not guaranteed to be economically viable.

The operating efficiency of the facility, at optimum operation conditions, is predicted to be 21.5% when operated for electricity only, and 36% when operating at optimal integration with the pulp and paper mill located next to the facility (i.e., when as much waste heat as possible is used by the pulp and paper mill).[40] The actual energy output of the facility in 2014 was 258 GWh; its actual operating efficiency has not been reported.[41] Note, when combined heat and power facilities are operated optimally (that is, when as much waste heat is used as possible), they are technologically capable of achieving an efficiency rate of more than 80 percent, far greater than the 36% optimal efficiency for Nova Scotia Power's Point Tupper facility.

Woody fuel for the facility obtained from forest harvests is supposed to be only that for which there is no practical higher value as determined by local market conditions.[42] However, several hardwood product manufacturers have reported that they are either going out of business or reducing output due to shortage of hardwood supply, which they blame at least in part on the NSPI biomass plant.[43]

3.4 Analysis

To date, Nova Scotia has not assessed or addressed the carbon emission implications of forest biomass energy, although Nova Scotia's Renewable Electricity Plan of 2010 recognized that biomass used for electricity is relatively inefficient compared to using biomass to heat water or living spaces.[44] While the province required biomass projects under the COMFIT program to be "combined heat and power," the province does not define this term by way of a minimum efficiency, nor require operators to report the efficiency level their facilities achieve. Without a minimum efficiency requirement, and without a reporting requirement, there is no way to gauge the effectiveness of COMFIT biomass projects with respect to carbon emissions mitigation.

Likewise, Nova Scotia has not yet established minimum efficiency requirements for biomass energy projects under the province's *Renewable Electricity Regulations*. Forest biomass electricity categorically qualifies as "renewable" provided that forest biomass fuels come from a sustainable harvest (but stops short of defining a sustainable forest harvest).

Furthermore, despite the admirable purposes listed under both the *Forests Act* and the *Crown Lands Act*, Nova Scotia's Department of Natural Resources has not yet developed regulations to ensure that forest harvesting in general, and biomass harvesting specifically, does not compromise forest biodiversity health and forest productivity.

4. Biomass Energy Policy: New Brunswick

4.1 Renewable Energy Policy

Under New Brunswick's *Renewable Resources Regulation*, NB Power (New Brunswick's Crown power corporation) must ensure that by 2020, 40% of the total in-province electricity sales are from renewable resources.[45] Biomass energy qualifies as an eligible source. Unlike in Nova Scotia, the Renewable Resources Regulation stipulates that all electricity purchased from eligible renewable energy suppliers will be purchased at a fixed rate of $95.00 per MWh (9.5 cents per kWh). In contrast, renewable energy purchases in Nova Scotia are generally based on competitive bidding (save for energy purchased through the COMFIT program, and for NSPI's Point Tupper biomass energy facility, as discussed above).

New Brunswick's 2007 Climate Change Action Plan includes a goal to reduce New Brunswick's greenhouse gas emissions to 10% below 1990 levels by 2020. The Plan includes a commitment to utilize forest biomass to help achieve this goal. The province's 2011 progress report on this goal included the allocation of Crown land biomass harvests in 2010 among the accomplishments achieved in working towards the goal.[46]

4.2 Biomass Harvesting Policy

New Brunswick also has a high proportion of privately owned land relative to the rest of Canada, although less than Nova Scotia. Forty-seven percent of New Brunswick is provincial Crown land, while 51% is privately owned (34% small private holdings and 17% industrial holdings). Similar to Nova Scotia, the upshot of this ownership pattern is that biomass harvesting regulations must apply to private as well as Crown lands to be effective throughout the province.

New Brunswick does not have regulations applicable to biomass harvesting. The New Brunswick Department of Natural Resources (NBDNR), however, has developed a biomass harvesting policy, which applies only to Crown land.[47] At present, there is no policy governing biomass harvesting on private land. The policy defines forest biomass as all above-ground components of trees that were not previously defined under the NBDNRs' utilization standards for Crown Land. The policy restricts biomass harvested for energy purposes to tree tops, branches, foliage, non-merchantable woody stems of trees and shrubs, dead woody material, and residue from tree chipping. The soil litter-layer, stumps, and roots are not eligible for biomass harvest.

The policy requires that biomass harvesting not reduce the predicted future growth of the harvested site, although it also recognizes that further research and analysis is necessary to fully understand the impacts of removing forest biomass on forest growth and ecological values. The policy also recognizes that biomass harvesting may not be compatible with a full range of ecological values. The policy offers that the province's direction on biomass harvesting may shift as new information becomes available; however, the policy was due to be reviewed in 2012, and has yet to be amended.

The policy states that the selection of stands appropriate for biomass harvesting will be based on a DNR approved mapping software decision support model, so that a pre-defined growth rate of stands can be sustained. The key requirement of the policy is for biomass removal to not result in reduced forest growth based on predictive forest growth models.

Other relevant legislation includes the province's *Crown Lands and Forests Act*, which states that the Minister of Natural Resources is responsible for the development, utilization, protection and integrated management of the resources of Crown lands, including habitat for the maintenance of fish and wildlife populations.[48]

4.3 Analysis

New Brunswick has embraced forest biomass electricity generation as a component of its renewable energy program. As in the case with Nova Scotia, New Brunswick has not yet established minimum efficiency requirements for forest biomass to qualify as renewable energy, nor has the province required biomass electricity facilities to demonstrate carbon emissions reductions relative to other energy sources.

New Brunswick is the only Maritime province to have a specific biomass harvesting policy, although it has not been made into a regulation. The policy applies only to Crown land, which is slightly less than half of New Brunswick's forestland, leaving the rest of the province's forestland open to unregulated biomass harvesting. Furthermore, the policy is narrow in scope, applying only to model-predicted future productivity of forest soils, and does not address the biodiversity impacts of biomass harvesting.

The New Brunswick government has been criticized for not promoting biomass heating opportunities at institutions such as schools and hospitals, where carbon emission benefits could be achieved by replacing oil heat with biomass heat.[49]

5. Biomass Energy Policy: Prince Edward Island

5.1 Energy Policy

PEI's Renewable Energy Act committed the province to obtaining 15% of its electrical energy from renewable sources by 2010.[50] Renewable energy sources include "organic material", that is, biomass. The province's 2008 Energy Strategy reiterated this goal, and added a goal to increase energy from renewable sources to 30%. The Strategy also includes a goal to reduce greenhouse gas emissions to 10% below 1990 levels by 2020, and to reduce CO2 emitted per MWh by 20% of 2008 emissions. The province's 2008 Climate Change Strategy includes a commitment to promote biomass heating systems in government buildings by providing incentives. The province also created a Joint Working Group on Biomass Heat in 2010 to assist with expansion in the use of biomass heat.

Biomass energy accounts for an estimated 10% of the province's total energy use, almost all of which is residential heating with firewood. The province has one biomass district heating system, located in Charlottetown, which uses municipal waste and wood biomass to provide heat to various nearby buildings. The system reportedly displaces over 16 million litres of heating oil annually.[51] Biomass-based electricity generation was not considered to be a renewable energy option in the province's 2008 energy strategy.[52]

The PEI government has shown support for biomass-based heating projects by issuing a request for proposals for switching some government buildings to biomass heat. Several schools and health facilities have now been converted to biomass heating systems. In a 2014 press release, PEI's Minister of Transportation and Infrastructure Renewal, Robert Vessey, stated "We know now that, in addition to sustainable energy, the existing [biomass heating systems] are creating cost savings…."[53] The press release claims that switching to biomass heating systems in 18 government buildings will save $120,000 in annual fuel costs.

5.2 Biomass Harvesting Policy

Prince Edward Island has the highest percentage of private land ownership in the Maritimes (and in Canada), with 88% of the land owned privately (with the remainder owned by the Crown). Any regulation of biomass harvesting would have to apply to private lands to be effective.

Prince Edward Island regulates biomass harvesting only if the biomass energy generation facility, or the forestry practices used to supply such a facility, receive public financial investment.[54] If not, then no additional regulation applies. For situations where the province's biomass regulations apply, whole-tree harvesting is not permitted if a site is clearcut (unless the area is being converted from forest to non-forest use), but is permitted if partial harvest techniques are used. As well, stump removal is not permitted unless the site is being converted from forest to non-forest use.

5.3 Analysis

Prince Edward Island's *Renewable Energy Act* includes biomass as an eligible renewable energy source, and does not stipulate minimum efficiencies, or require demonstrated carbon emissions reductions. However, PEI has so far avoided forest biomass electricity projects, and does not appear to be pursuing biomass electricity. PEI is the only Maritime province to specifically encourage biomass heating projects in government buildings, through a competitive bidding process, and to explore the potential for biomass district heating.

PEI's biomass harvesting guidelines restrict some harvesting practices, provided that the wood is destined for a facility that has received (or the harvesting itself received) financial government assistance.

6. Biomass Energy Policy: Massachusetts, USA

In 2010, public opposition to some 100 MW of proposed biomass electricity developments led the Massachusetts government to commission the Manomet study (described below), and to put a moratorium on biomass electricity development pending the results of the study.[55] Following the release of the study, the Massachusetts Department of Energy Resources (DOER) released draft changes to its Renewable Energy Portfolio Standard. After approximately a year of consultations, the finalized Standard was released in August 2012.[56] The proposed private-sector biomass projects, which had been put on hold, did not meet the efficiency requirements of the new Standard, thus did not qualify for the State's renewable energy credits and were therefore no longer economically viable pursuits and did not proceed.

The revised Standard requires all woody biomass energy facilities to generate power at a minimum of 50% efficiency to receive renewable energy credits at a rate of 50%, and at minimum of 60% efficiency to receive full credits. Efficiency is to be measured quarterly, and tonnage of biomass fuel used reported annually. Any forest cutting for biomass fuel must be done in accordance with a forestry plan prepared by a licenced forester, which indicates the allowable harvest for the site. Furthermore, biomass power plant owners must demonstrate that the facility will reduce lifecycle carbon emissions by 50% over 20 years relative to the operation of a new combined cycle natural gas electric generating facility, using the most efficient technology available as of a date as determined under section 14.05(1) of the Standard. The State also committed to 5-year assessments of the environmental impact of the State's biomass energy industry, and to offer outreach education and training to the forestry and biomass industries to help them comply with the new regulations.

The DOER Commissioner, Mark Sylvia, was clear that the new Standard is the State's response to the results of the Manomet study and recognition of forest biomass energy's potential negative impact on the State's goal to reduce GHG emissions by 80% by 2050.[57] Sylvia also stated that Massachusetts still sees a role for biomass energy, but one that is focused on efficient use of the States' limited wood resource.[58] Response to the revised Standard from the forestry industry was not favourable: "the new regulations effectively eliminate biomass as a renewable energy source … by setting infeasible efficiency requirements…."[59] Response from some conservation organizations was positive: "These standards are the first in the world to set a performance requirement for biomass. The new framework is critical to reducing carbon emissions and protecting forests, both in Massachusetts and nationally."[60] Other conservation organizations were less enthused: "there should not be any subsidies for tree-fueled biomass energy, whether it is done efficiently, or inefficiently, because in both cases it will increase pollution, deforestation and carbon emissions."[61]

PART III: Science of Biomass Energy and Carbon Emissions

7. Biomass Energy and Carbon Emissions Background

"Burn a tree, grow a tree: it's simple, it's carbon neutral." The assumption that biomass fuel is inherently carbon-neutral is widely held among renewable energy policy makers. This belief is intuitive when considering simplified models of biogenic carbon cycling between the atmosphere and vegetation. Conceptually, the regrowth of forest vegetation is assumed to sequester as much carbon as is released to the atmosphere when the harvested vegetation is burned. There is a continual cycling of carbon, the reasoning goes, between terrestrial pools of carbon and the atmosphere. What goes up in smoke will be absorbed in new forest growth, and therein, equilibrium between carbon in vegetation and carbon in the atmosphere is maintained. Fossil fuels, in contrast, represent a one-way flow of carbon from fossilized sources (oil, coal, natural gas) to the atmosphere.

This reasoning has been applied to accounting for carbon emissions under the Kyoto Protocol. Under the Protocol, carbon released when burning biomass fuels (that is, vegetation or vegetation-derived fuels), are exempt from being counted towards a nation's GHG emissions. This exemption is generally reflected, in turn, in most national or regional regulations or standards that define renewable (i.e., carbon-neutral) energy sources and their eligibility for various subsidies or preferential rate prices.

The assumption that forest biomass is a carbon-neutral fuel source is predicated on an intuitive view that harvested biomass is replaced with new growth of biomass. Much like carrots grown in a garden, so long as an equal quantity of carrots is grown to replace the ones harvested, the overall amount of carrots growing, measured annually, will be constant. This assumption has been applied to ecosystem and landscape level accounting of forest carbon storage and carbon emissions from the harvest and burning of forest biomass.

This rhetoric is a common refrain. Consider the entry under biomass energy on Wikipedia: "Although the burning of biomass releases as much carbon dioxide as the burning of fossil fuels, biomass burning does not release "new carbon" into the atmosphere, which the burning of fossil fuels does."[62] Take for another example the United States-based National Alliance of Forest Owners:

> *"The carbon neutrality of forest biomass used to produce electricity and heat is a long-established convention in greenhouse gas (GHG) accounting. The prevailing view in the science community, as acknowledged by the Environmental Protection Agency (EPA), is that carbon emissions from biomass are offset by the prior absorption of carbon through photosynthesis that created the biomass. In other words, the carbon that enters the atmosphere was previously absorbed from the atmosphere and will be reabsorbed when new biomass is grown…."*[63]

As detailed in the policy review section above, most international and regional policy and regulations reflect this widely-held assumption. Nonetheless, forest scientists question the soundness of the biomass carbon-neutrality assumption; below are four potential "failures" of the current forest biomass fuel carbon-accounting.

8. Issue 1: Failure to Account for Changing Land Use

In 2009, Princeton University scientist Timothy Searchinger and twelve colleagues challenged prevailing rhetoric on carbon emissions and bioenergy in a short paper published in the journal Science, titled "Fixing a Critical Climate Accounting Error."[64] Their article drew attention to a "far-reaching but fixable flaw that will severely undermine greenhouse gas reduction goals." The flaw, according to the authors, lies in the failure to account for changes in land use due to pressure to grow biomass fuels and the impact this change may have on carbon storage on the lands where the biomass is harvested. Under the faulty accounting, the authors explain, changing land use that results in converting an ecosystem with a high level of carbon storage to one with a low level of carbon storage is not accounted for, despite the obvious net loss of carbon to the atmosphere. Under a worst-case scenario, Searchinger et al. suggest that a global conversion of natural forests and savannahs to biomass fuel crops could release up to 37 gigatones of carbon dioxide into the atmosphere, which is comparable to total human emissions up to the present. Searchinger et al. note that biomass fuels release just as much or more carbon into the atmosphere as fossil fuels per unit of energy. Biomass fuels are only carbon-neutral to the extent that the released carbon is eventually reabsorbed by growing vegetation at some later point in time.

By way of an example of the flaw illuminated by Searchinger et al., consider a hypothetical old-growth forest that stores 300 tonnes of carbon per hectare through time. Leaving this old-growth forest alone will ensure that, barring disaster on a landscape-level scale, the carbon will continue to be sequestered in the terrestrial carbon pool. Minor cutting and minor natural events that kill trees, but that do not compromise the integrity of the forest, have only a nominal effect on carbon storage because the forest as a whole maintains a steady-state equilibrium between growth and loss; such is the dynamics of old-growth forests.[65] Both the carbon stored and the capacity of the forest to store carbon per unit area remains more or less constant. Consider, however, if a hectare of this forest is clear-cut, the wood used as biomass fuel, and a biofuel crop that stores 50 tonnes of carbon per hectare over time is planted in place of the forest. Three-hundred tonnes of carbon would be released to the atmosphere in the short term, until the loss is reduced to 250 tonnes as the new 50 tonne capacity is reached over the years or decades necessary to grow the new vegetation. This change in carbon storage capacities, or pools, does not register in current carbon accounting; any biomass burned for energy, either from the old forest or from the new biofuel plantation, would be considered carbon-neutral, despite the obvious and more or less permanent transfer of carbon from the terrestrial pool to the atmosphere. The change in the forest is not considered a land-use change because it could technically still be called a forest.

It is worth mentioning a common misconception with respect to old forests and carbon, wherein the conversion of old-growth forests into plantations is considered a positive climate change mitigation action (based on the faulty reasoning that fast-growing seedlings store more carbon than old forests).[66] Aside from the obvious negative biodiversity and ecosystem services implications of this,[67] converting old-growth forests to plantations or naturally regenerated young forests transfers the carbon stored in these forests to the atmosphere. Forests, and old-growth forests in particular, are reservoirs of carbon.[68] From a carbon emissions mitigation point of view, the best land-use option is to leave old-growth forests standing.[69]

9. Issue 2: Failure to Account for the Effect of Harvesting Method on Carbon Storage over Time

In the context of eastern North America, the magnitude of impact of replacing old forests with short-rotation fibre crops is minimal due to the fact that old forest is now exceedingly rare in this region.[70] Nonetheless, the carbon capacity of a forest ecosystem is also an important factor in working forests, i.e., forests that are actively managed for forest products, as are the vast majority of the forests in the Maritimes provinces. Fibre that is removed from working forests and burned would either have been removed for another product that would have possibly continued to store carbon, or it would have been left in the forest. Carbon levels in working forests are generally kept at below the forest's full carbon capacity, as forests continue to accumulate carbon long after they are deemed optimally economical to harvest. When left un-harvested, forests that are not at their peak carbon storage capacity accumulate carbon.[71]

Researchers in Vermont carried out empirical observations and modeling tests to quantify the impact of various harvesting scenarios on carbon storage over time in eastern hardwood forests.[72] These researchers found that increasing intensity of forest harvesting (i.e., from frequent but low removal partial harvesting to less frequent but complete removal clearcuts) corresponds with less carbon stored in the forest over time. Carbon storage over time was highest in forests left uncut, even when wood cut in harvesting scenarios was considered to be manufactured into durable products and thus continue to store carbon. Reducing harvesting levels allowed forest carbon levels to rise towards capacity, while increasing harvesting levels depleted carbon levels. If the wood removed from the forest was burned as biomass fuel, rather than manufactured into durable products, the impact of harvesting on carbon storage would be greater.

The Vermont study focused on forest harvesting impacts on the immediate harvest site (i.e., site- or stand-level impacts). Forest researchers in Massachusetts (Thompson et al.) asked a similar question about the impact of forest harvesting on forest carbon storage, but at a State-wide level, and with a focus on increased biomass fuel harvesting.[73] Under a business-as-usual scenario (i.e., continued recent harvesting trends), Thompson et al. estimated that carbon sequestered by the State's forests would increase by 1.9 million tonnes over the 50-year modeling horizon. Adding forest biomass harvesting to the model, on the other hand, was predicted to result in a net loss of carbon from the forest to the atmosphere, between 7.3 and 9.9 million tonnes. The authors concluded that pursuing a renewable energy policy that relies heavily on biomass power would likely diminish the forest carbon sink.

10. Issue 3: Accounting for Carbon Re-sequestration Time Delays

10.1 The Manomet Study

Perhaps stemming from the results of Thompson et al.'s study and others' questioning of the biomass carbon-neutrality assumption, the State of Massachusetts commissioned the Manomet Center for Conservation Studies to complete a life-cycle analysis of carbon emissions from forest harvesting for biomass energy. Released in 2010, the study confirmed that forest biomass, in the Massachusetts context, is not inherently carbon-neutral at the time of burning.[74] The authors described the notion of a carbon debt that is incurred when biomass is burned, but which can be "repaid" over time, as the harvested forest regrows. The magnitude of the debt, thus the time required to repay the debt, varies according to (1) the efficiency at which the biomass is burned (can range from roughly 20 to 80 per cent); (2) the nature of the forest harvest (intensive fibre removal through whole-tree clearcutting versus lower-impact partial harvesting with structural retention); (3) the nature of land-use and forestry management of the biomass harvest site post-harvest; and (4) the type of fossil fuel energy system replaced by the biomass fuel.

Under best case scenarios (i.e., lower intensity harvesting, highly efficient use of biomass, and replacement of inefficient use of fossil fuels such as older coal-fired power stations), the carbon debt can be repaid within an estimated 10 to 20 years, after which net carbon emissions start to decrease. Under worst case scenarios (intensive forest harvesting, inefficient use of biomass, replacement of highly efficient fossil fuel use such as a modern natural gas power station), the carbon debt will not be repaid for over a century (i.e., net carbon emissions increase).

The authors also offered a snap-shot comparison of accumulated net carbon emissions from various energy sources at 40 years in the future (i.e., 2050). Replacing a coal-fired power plant with a biomass-fired plant would result in a net increase in emissions of 3% by 2050. Replacing a natural gas-fired power plant with biomass would result in a 110% net increase in emissions by 2050. Replacing oil-fired heating with biomass fuel, on the other hand, would result in a net reduction of emissions by 25% by 2050.

A point to stress is that paying off the carbon debt in Manomet's model, at whatever point in the future, depends entirely on an assumption that the forest will successfully re-grow to the pre-harvest volume level. The Manomet study does not entertain scenarios where land-use changes post-harvest (the accounting flaw described by Searchinger et al. in section 8 above), where biomass harvesting represents a change in harvesting practices (described in section 9 above), or where the nature of the biomass harvest reduces the carbon carrying capacity of the harvested site through reduced productivity (described in section 11 below). Such factors, if added to the model, would intensify the negative impacts of forest biomass harvesting and burning on carbon emissions mitigation.

10.2 Critiques of the Manomet Study

One criticism of the Manomet study is that its authors chose an incorrect starting point for the base level of forest carbon storage.[75] The starting base value for the forest carbon pool should be zero, according to the critique, thus whatever forest exists now in Massachusetts should be counted as carbon credit. Burning the forest simply uses up the credit, and the re-growing forest builds up the credit again. Manomet responded to this issue by explaining that their study was designed to answer the question of how present and future forest biomass energy production will affect carbon emissions against a business-as-usual scenario, thus any reference to historical forest growth is irrelevant.[76] The critic missed, apparently, the essential point of the study, that is, whether, to what degree, and for how long forest biomass burning for energy will increase net carbon emissions to the atmosphere. The baseline starting point of the study was necessarily present conditions. It is difficult to see any value in making 'bare ground' the reference point for assessing the impacts of biomass harvesting and use for energy on forest carbon storage, given Massachusetts is naturally a forest-covered state.

Another critique suggested that Manomet incorrectly chose to look at stand-level impacts rather than landscape-level impacts.[77] The point in the critique is that a trend observed at the spatial scale of a forest stand does not necessarily give an indication of trends over the entire forest management area. The amount of above-ground carbon in one stand could be reduced, more or less, to zero by clearcutting it for biomass energy, but the loss of carbon in that stand is off-set by growth in other stands, so that there is a steady-state of forest-stored carbon from a landscape-level view. So long as the overall harvest within the management area does not increase, there is no net loss of carbon from year to year. While the point is valid, it is not a fair criticism of the Manomet study as it only applies to forest harvesting that is already in equilibrium with forest growth. The Manomet researchers did use stand-level dynamics to ascertain stand-level carbon storage impacts, but applied these results to a landscape where the biomass harvest is additional to the business-as-usual harvest. So long as the modeled harvesting is an increase over baseline harvest levels, that is, harvesting for other products is not decreased proportionately, then there is an immediate drain on carbon storage rates once the harvested biomass is burned. The time to reach a new equilibrium between harvesting and growth is the very issue Manomet sought to address.[78]

Another criticism of the Manomet study (and the only to be published in a peer-reviewed journal), is that increased demand for forest biomass products will encourage owners of farmland to establish biomass crops, thereby possibly increasing the overall amount of carbon stored.[79] Conceptually this scenario is possible, but would depend on factors such as (1) availability of non-forested land for biomass crops, (2) whether the land would have been allowed to regrow to natural forest, (3) whether forest was removed to allow for the biomass crops, and (4) whether the economic incentive is strong enough to persuade landowners to switch from other land uses to biomass crops. It remains to be seen whether this theory would pan out in reality, and no empirical evidence has been offered to support this.

Finally, O'Laughlin, a researcher from the University of Idaho, in addition to the points raised above, criticised the Manomet report by framing the forest biomass question in terms of an either-or debate between using forests for biomass or leaving them to "decay and burn."[80] The lack of academic rigour in proposing this false dichotomy is surprising, but the sentiment is indicative of the view of some advocates of biomass energy, and perhaps indicative of a paradigm view that forests exist by the grace of human intervention. Left to their own, the view suggests, forests will fall down and rot or be ravaged by insects, disease or fire. That such a view of forest ecosystem dynamics still exists is unfortunate, given the abundance of forest ecosystem knowledge to the contrary.[81] O'Laughlin also relies on an argument by majority, as well as a straw man argument, with his statement that "the rest of the world considers bioenergy is a low-carbon source of renewable energy, but the Manoment Center report does not." While Manomet may be among the first to propose a more complex view of forest biomass carbon flux relative to fossil fuels that challenges the conventional view, this does not make the findings inherently wrong. Also, Manomet allows that there is a role for forest biomass energy in carbon emission mitigation, provided it is done within parameters that maximize its effectiveness. Finally, O'Laughlin states that it is unnecessary to consider short-term carbon emissions (before 2050), because "the buildup of atmosphere carbon problem is a long-term problem, so a long-term sustainable approach is appropriate…." However, it is generally accepted that mitigation efforts must focus on near- as well as long-term solutions, and that emissions need to peak and decline by 2030 as described in the IPCC's 2007 Summary for Policy Makers.[82]

10.3 Additional Research on CO2 Emissions of Forest Biomass: Ontario and Norway

Following on the heels of the Manomet report, researchers from the University of Toronto and the Ontario Forest Research Institute released a study concluding that generalized assumptions about the GHG mitigation benefits of biomass fuels should not be used to inform public policy and decision making.[83,84] Based on the forest of the Great Lakes—St. Lawrence region of Ontario, McKechnie et al. found that the conventional assumption of carbon-neutrality for biofuels overstates the GHG mitigation performance of biofuels, and fails to account for delays in mitigation of carbon emissions. They suggest that forest bioenergy policies that fail to address carbon flows in the forest may achieve emissions reductions on paper but not in reality. McKechnie et al. found that for the forest system they studied, biomass electricity would increase emissions relative to coal-fired electricity for some 16-35 years. The researchers also compared emissions from forest-sourced ethanol to emissions from gasoline. Ethanol produced from trees would increase emissions for more than 100 years relative to burning gasoline.

Researchers continue to better quantify the impacts of forest biomass harvesting on carbon emissions. Holtsmark, a Norwegian researcher, examined the assumptions used in five studies on this issue, including the Manomet and McKechnie studies, noting that results varied among studies.[85] Holtsmark looked at just the forest harvesting step of the forest biomass fuel emissions question; that is, he did not address the effect of fossil fuel displacement on emissions. Holtsmark notes that the Manomet report and two studies by Cherubini et al.[86,87] found that while atmosphere carbon increased in the short-term, it decreased as the forest attained its former volume. In contrast, Holtsmark's own study[88] found that atmosphere carbon levels increased for a century due to biomass harvesting, and the 'carbon debt' remained high for the 250 years of the model horizon. The key difference between these studies, Holtsmark explained, is whether a single biomass harvest (Manomet and the Cherubini et al. studies) or multiple biomass harvests (Holtsmark) is assumed. The more realistic scenario, Holtsmark asserts, is multiple harvests for biomass over time, along with harvest at the point when trees reach economic maturity, rather than maximum carbon accumulation. Applying these assumptions, Holtsmark found that "an increased harvest level in forests leads to a permanent increase in atmospheric carbon dioxide concentration… wood fuels are not carbon neutral, neither in the long term or the short term." Again, Holtsmark's findings could be tempered by adding the mitigating effect of displacing fossil fuels. However, it is reasonable that the Manomet model may have underestimated the negative impact of forest biomass fuels on carbon mitigation efforts, given the single harvest assumption applied in their model.

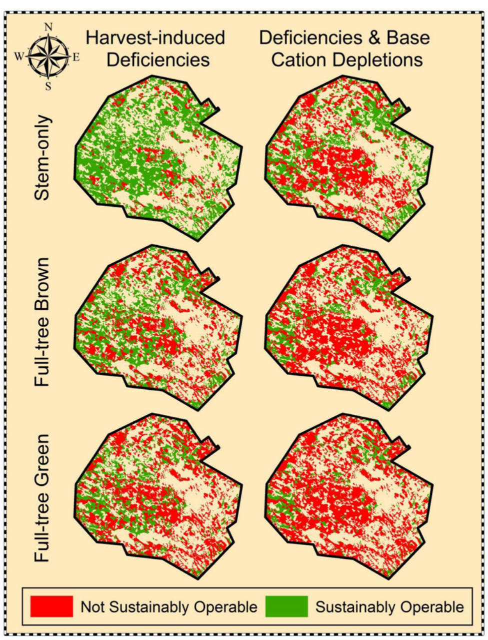
11. Issue 4: Failure to Account for Decreased Forest Productivity Due to Biomass Harvesting

Forest biomass harvesting tends to remove material that is not usable for other products, such as tree tops, branches, small trees, crooked trees and decayed trees,[89] and as such would often otherwise be left behind in the forest following a conventional clearcut harvest. The bulk of nutrients in a tree are found in its bark, small branches and leaves or needles, which is much of the material removed during a biomass harvest. The harvest method used in biomass harvesting is known as whole-tree harvesting, whereby the entire above-ground portion of the tree is removed from the forest and used.

Removal of forest biomass changes several attributes of forest soils that may impact forest productivity. Studies have documented nutrient loss, changes in soil acidity, soil mechanical damage such as erosion and compaction, and compositional and abundance changes in soil organisms caused by whole-tree harvesting,[90] all of which have potential to reduce the productivity of forest soils thus reduce future forest growth. In the province of Nova Scotia, most forest soils are vulnerable to declines in productivity associated with nutrient loss, due to increased acidity of the province's soils, largely caused by acid precipitation.[91]

In 2009, the Nova Scotia Department of Natural Resources (NSDNR) commissioned a more detailed study of the province's soils to determine their resilience to productivity decline associated with nutrient loss caused by whole-tree harvesting. The NSDNR received the report in 2012, but has yet to release the report.[92] The researcher who conducted the study published some of the results as a Master's Thesis;[93] NSDNR permitted him to release information only for federally-owned Kejimkujik National Park. The results, while geographically limited, suggest that biomass harvesting in Nova Scotia can result in decreased forest productivity.

Figure 2: modeled sustainability (based on net nutrient depletion) of conventional (stem only) and winter biomass (full-tree brown) and summer biomass (full-tree green) harvest in Kejimkujik National Park; beige areas are water or otherwise non-forested.[94]



In Figure 2 (left), green represents soils that can sustain a harvest without a loss in forest growth productivity, while red represents soils that cannot sustain a harvest without a loss in forest productivity. (The white areas are water or wetlands.) The left column shows the impact on productivity from harvesting alone, while the right column shows the impact of harvesting in conjunction with other factors at play (particularly acid precipitation). The first row of images shows the impact of conventional clearcutting, that is, where branches and tops are left in the forest. The second row shows the impact of whole-tree clearcutting during the winter, and the third row shows the impact of whole-tree clearcutting during the summer.

While there are significant uncertainties, regional variation (at all scales), and a dearth of long-term studies, there is evidence for forest productivity decline due to increased demand for biomass fuels due to the impacts of whole-tree harvesting on forest soils.[95] Declines in forest productivity equate to declines in the carbon carrying capacity of a site for the next forest or biomass crop. In situations where the impacts of whole-tree harvesting on forest productivity are known, or where there is known risk, prudent carbon modeling should account for productivity declines. Nova Scotia's soils, by way of example, may be particularly at risk of forest productivity declines.[96]

Wherever productivity declines following biomass harvesting, the assumption that forests will eventually capture all of the carbon released no longer holds. While conversion of forest to biomass crops has been considered in the forest biomass carbon emissions debate (land-use change), none of the literature or forest biomass carbon accounting models has so far considered the emissions and storage impacts of declines in forest productivity resulting from biomass fuel harvesting.

Visible topsoil erosion, three years post biomass harvest by Northern Pulp Nova Scotia Corporation

PART IV: Biomass Energy and Biodiversity

12. Impact of Biomass Harvesting on Biodiversity

Increased demand for forest biomass as a fuel source may (1) increase total forest area cut due to increased commercial operability of forest stands, and (2) increase fibre removal per area harvested relative to conventional clearcuts or partial harvests by removing types of wood not normally removed during conventional harvesting, such as tree tops and branches, and small-diameter, crooked, damaged, decayed and otherwise non-merchantable trees.[97] Given the critical role of snags, deadwood, canopy cover and fine woody material and foliage in the forest ecosystem, the developing demand for forest biomass fuel represents potentially significant risks to forest biodiversity and productivity proportional to the intensity and extent at which biomass fuel removal is carried out.

Note, our review of studies on the impact of biomass harvesting on biodiversity were limited to studies from eastern North America's Northern Hardwood Forest, eastern Boreal Forest and Acadian Forest (specifically, Ontario, Quebec, the Maritime provinces, Wisconsin, Michigan, Maine and the New England states), and to meta-analyses of North America studies.

We reviewed papers containing research and / or forest management recommendations based on research relevant to the impact of increasing harvesting intensity on biodiversity in eastern North American forests. The studies were based in the following forest types: Acadian Forest (Maritime Provinces and Maine); Northern Hardwood Forest (New England, Wisconsin and Michigan); Great Lakes-St. Lawrence Forest (Ontario); Boreal Forest (Ontario and Quebec).

The papers were grouped by the following themes: biodiversity (either generally or specific taxa); coarse woody material and/or snags and/or cavity trees; forest structure; site productivity; soil quality; and nutrient dynamics. Naturally some studies addressed more than one theme.

The studies addressing biodiversity dealt with the following groups of organisms: amphibians, birds, small mammals, ground vegetation, bryophytes specifically, lichens, trees, soil fauna and flora, non-soil-dwelling insects, and 6 with a variety of taxa.

Increased intensity of forest harvesting through clearcutting, whole-tree harvesting and / or reduction of coarse woody material has been shown to (1) reduce abundances of various components of forest biodiversity, notably certain amphibian, herbaceous vascular plants, bryophyte, lichen, tree, saproxylic insect, soil fauna and bird species; (2) change the community composition of various taxa, notably birds, insects and ground vegetation; (3) decrease survival rates for two forest bird species; (4) decrease nutrient levels in certain forest soils; and (5) decrease site productivity in certain forest study sites.

The causal mechanisms driving negative effects on forest biodiversity include (1) reduced coarse woody material habitat, across a range of decay classes, (2) reduction of snag and cavity tree habitat, (4) loss of food resources provided directly and indirectly by fallen and standing dead wood and declining trees, (3) loss of canopy closure resulting in lower microclimate suitability (increased temperatures and light, and decreased moisture levels), and (4) reduced habitat at a landscape level resulting in abundance declines greater than that explained by loss of stand-level habitat alone.

13. Biomass Harvesting Impact on Amphibians

Forest harvesting has been shown to reduce abundances of some amphibian species (particularly salamanders) when the harvesting reduces coarse woody material on the forest floor, reduces canopy cover, or increases forest floor disturbance.[98,99,100,101,102] In a review of studies across North America, researchers found that the negative impacts of clearcutting on amphibians can be long-lasting.[103] Generally, negative impacts of forest harvesting on amphibians are associated with clearcut and near-clearcut harvesting (such as shelterwood harvesting). Researchers suggest that clearcutting, both with and without coarse woody material retention, has a largely negative effect on juvenile and adult terrestrial states of most forest amphibian species due to the drier and warmer microclimate conditions, and reduced leaf litter and food resources that result from clearcutting.[104] These researchers also noted that the negative effects of clearcutting are pervasive and more or less consistent across regions as diverse as the north-eastern, mid-western and south-eastern USA, and that clearcutting is directly implicated in the loss of suitable habitat and in the reduction of population size through mechanisms such as reduced terrestrial survival due to mortality from lack of refuge or food, desiccation and inability to evacuate from clearcuts. The authors stressed that the basic needs of amphibians require movement overland, and that every aspect of their lives in the terrestrial environment is affected by water loss, and suggest that water loss due to clearcutting explains the reduction in amphibian activity, growth rate and survival documented in their studies.

Studies of partial harvesting did not find negative impacts of the harvesting on amphibians.[105]

14. Biomass Harvesting Impact on Birds

In a review of studies of avian communities in Nova Scotia and New Brunswick, researchers concluded that forestry practices can result in dramatic changes in habitat available to biodiversity, including birds, and recommend that snags, cavity trees and coarse woody material be maintained during forest harvesting as critical habitat for dependent species.[106] Other researchers recommend maintaining canopy closure of at least 70% and a density of large trees (>30cm dbh) of at least 80 stems per hectare to ensure a full complement of bird species.[107]

Woodley et al. found that richness and abundance of cavity-nesting birds is highest in non-cut stands, followed by selection-harvested stands, followed by naturally regenerating clearcuts, followed by plantations.[108] They suggest that retention of snags and cavity trees may help ensure survival of populations of some, but not all, cavity-dependent birds in clear-cuts and plantations, and that other cavity-dependent species will require areas of older mixed-wood forest.

Betts et al. found that population decline of blackburnian warblers occurs more rapidly than expected from habitat loss alone as the surrounding matrix of low-quality habitat increases due to timber harvesting.[109] Building on this study, Zitske et al. found that reduction of habitat not only reduced abundance of blackburnian and black-throated green warblers, but also resulted in lower within-season survival rates for the individuals observed.[110] The authors found that survival for the two species studied was 12 times greater in landscapes with 85% habitat than in landscapes with only 10% habitat.

In a study of small mammals' response to forestry practices in New Brunswick, Bowman et al. noted a strong relationship between red-backed voles and coarse woody material, but also did not detect a strong influence of forest management on abundance and richness of small-mammal species.[111] In a study in Ontario Boreal Forest, Pearce and Venier found that abundance of red-backed voles was linearly related to stand age and volume of downed logs, and that deer mice were abundant in both recent clearcuts and in mature forest, but abundance declined sharply 5-15 years after a clearcut.[112] Pearce and Venier also noted a strong year-to-year variation in population levels that was independent of forest disturbance, thus requiring long time frames to accurately detect tends due to forest management practices. In a small mammal study in Maine, Fuller et al. suggest that forest cutting that maintains structural attributes of mature forest may be beneficial to small mammals and their associated predators.[113]

In a study in Ontario's Great Lakes—St. Lawrence Forest, Holloway and Malcom found that both northern flying squirrel and red squirrel densities were lower in shelterwood cut stands 3-10 years following harvest than in uncut forest, and that densities of both species were strongly correlated with densities of large spruce and hardwood trees, and with snags in conifer sites.[114] The authors found that the density of eastern chipmunks was correlated to volume of downed woody material and density of declining trees. The authors found that southern flying squirrels were more numerous in selection harvested stands than in old-forest areas, and that they were associated with mast trees at the landscape level (but not at the stand level). In a following study in the same forest type, Holloway and Malcom noted a close association between northern flying squirrels and decayed trees.[115]

Similarly, in a study in New Brunswick, Ritchie et al found a higher frequency of flying squirrels in old forest of mixed conifer and deciduous trees.[116] They also found that flying squirrels were less likely to occur at sites as the amount of surrounding non-habitat area increased. The authors recommend maximizing area of old forest, maintaining tree species diversity and minimizing open areas to help ensure favourable landscape characteristics for northern flying squirrels. The authors also noted that they did not detect an effect of landscape pattern on abundance of northern flying squirrels.

15. Biomass Harvesting Impact on Soil Organisms and Above-ground Insects

In another review of studies on soil organisms, Marshall commented that forest harvesting affects the distribution, composition and activity of soil organisms due to changes and reductions of organic matter and changes to microclimate and ground vegetation.[117] Marshall suggests that adverse effects of forest harvesting on soil organisms can be mitigated by maintaining plant biodiversity, minimizing soil compaction, avoiding extreme microclimatic conditions, and providing refugia for re-colonization by the biota.

In a study of Boreal mixed forest in Quebec, Bird and Chatarpaul found soil microarthropod abundance decreased following whole-tree harvesting more so than following conventional clearcutting (68% versus 56% reduction) but an effect on community composition was not detected.[118] In a study in northern hardwood forest in Quebec, Moore et al (2002) found no adverse effect of low-intensity partial cutting or strip cutting on soil fauna 6-12 years after the harvest.[119]

In a study of deadwood-dependent insects in the Great Lakes – St. Lawrence forest of Ontario, Vanderwel et al found that abundance of various taxa correlate to abundance of deadwood by decay class.[120] The authors conclude that wood-inhabiting insect biodiversity can be best maintained by ensuring overall amounts of CWM are maintained, in both early and late stages of decomposition.

Work et al. found a negative effect of forest clearcut harvesting and deadwood removal on abundance of forest beetles in a study in Boreal Forest in Quebec.[121] The authors also found that removal of deadwood reduces abundance of below-ground species of soil microarthropods, and that some deadwood-dependent species of diptera show preferences for specific tree species and decay classes of deadwood. The authors suggest that a variety of species and decomposition classes must be maintained within stands to maintain insect diversity, and that current retention levels post-clearcut harvesting in Quebec's Boreal Forest are insufficient to sustain arthropod communities found in later successional mixed and conifer dominated forests. Also in Quebec's Boreal Forest, Klimaszewski et al found that the community composition of Rove beetle species was similar between uncut forest and group-selection harvested forest. Clearcutting, however, significantly changed community composition of the beetles studied.[122]

In a study of beetle diversity and community composition in Nova Scotia, Dollin et al found that stand age and harvest treatment affect species richness and composition, with younger stands having lower species richness and a significantly different suit of species than medium-aged or older stands.[123] Likewise, clearcut areas hosted lower species richness and markedly different species assemblage than unharvested stands. The authors suggest that forest management that emphasizes even-aged single-species stands may be harmful to Nova Scotia's forest insect diversity. In another study of deadwood-dependent beetles in Nova Scotia, Bishop et al did not find a significant difference in beetle richness between managed forests and naturally disturbed forests, and suggest that this may be due to the fact that both the managed forest and natural forest study sites contained large-diameter deadwood habitat.[124]

In a study in Maine, Thomas et al found that small (<0.2 ha) harvest gaps with living trees retained throughout the gap can maintain click beetle assemblages similar to that of an uncut forest.[125] The authors also recommend that forest management should ensure the temporal continuity of CWM, including different types of wood (hardwood and softwood), a range of decay conditions, and a range of diameter classes, especially larger diameters (>35 cm).

In a review of studies on the effects of forest management on insects, Spence et al state that the available literature shows that industrial forestry (clearcutting and other treatments associated with intensive forestry) results in local losses of species and dramatic changes in forest insect assemblages. Causal mechanisms were not discussed.[126]

In review of the state of knowledge on deadwood-dependent insects in Canada, Langor et al suggest that these insects are highly diverse and poorly understood, and that they are disproportionately threatened where deadwood is reduced following forest harvesting.[127] The authors recommend the development of habitat-classification system for deadwood to better identify deadwood habitats and associated species that are at risk from forest harvesting.

Several recent studies of insect diversity have yielded new species records and new distribution records for the Maritimes. In a study of Rove beetles at a study site near Fredericton New Brunswick, Klimaszewski et al noted 58 new distribution records for New Brunswick, including 15 new distribution records for Canada, and 6 species new to science.[128] Similarly, Majka and Pollock noted 38 new-to-science species records for various deadwood-dependent beetle taxa in the Maritime provinces.[129] The authors note that studies of deadwood-dependent beetles from across Canada indicate that populations are influenced by forest structure and disturbance, but that further study is needed to determine mechanisms that might lessen or ameliorate habitat fragmentation, loss of old-growth forest, reduction of CWM and other parameters of forests of importance to deadwood-dependent insects.

16. Biomass Harvesting Impacts on Ground Vegetation, Bryophytes and Lichens

In a review literature on herbaceous species in temperate forests, Gilliam noted that because species diversity is highest in the herb layer among all forest strata, forest biodiversity is largely a function of the herb-layer community.[130]

Mou et al found that ground vegetation community composition was altered following soil disturbance during clearcut harvesting in New Hampshire.[131] Similarly, in a New Brunswick study, Roberts and Zhu found that richness of forest-adapted ground vegetation decreased 20-24% 2 years after clearcut treatments, while richness of disturbance-adapted species increased 200-250%.[132] The cover of most vegetation types, and especially bryophytes, decreased after the clearcut treatments. The authors suggest that changes in species composition and diversity result from forest floor disturbance; they recommend minimizing forest floor disturbance, maintaining shade cover, and leaving uncut strips or patches of forest in areas containing ground vegetation species that are sensitive to forest harvesting. Roberts developed a three-dimensional disturbance severity model to characterize disturbance conditions caused by forest harvesting; the model showed strong short-term responses of the herbaceous layer to canopy removal, understory vegetation removal and forest floor and soil modification.[133]

Fenton et al found that the species richness of bryophytes was reduced by increased harvesting intensity at a study site in New Brunswick, but recovered within 4 years after harvest.[134] Changes in species composition, however, were significant and most pronounced following forest floor disturbance; liverworts, in particular, were lost from sites following forest floor disturbance. The authors suggest that reducing the area of forest floor disturbance may be effective in reducing immediate, local species loss. In conifer plantations in New Brunswick, Ross-Davis and Frego found bryophyte richness, evenness, and diversity to be lower relative to naturally regenerated sites.[135]

In a forest harvesting study in the Great Lakes—St. Lawrence Forest, Newmaster et al found that increased mineral soil disturbance and removal of downed woody material tended to correlate with lower herbaceous species diversity; mosses and ferns were the most affected ground vegetation taxa (lowest richness and abundance).[136]

Coarse woody material was shown to provide germination habitat for seeds of certain trees species and a fern species in northern hardwood forest.[137] In a comparison of plantations and natural forest in New Brunswick, Ramovs and Roberts recommended extending plantation harvest cycles in part to promote coarse woody material as one method to sustain critical habitat for vascular understory plant species in managed forests.[138] As well, the tops and branches from harvested trees was found to increase success of tree regeneration by acting as a physical barrier to browsing by white-tailed deer in a Pennsylvania study[139] and a New York study.[140]

In a review of north-eastern North America studies, Moola and Vasseur conclude that a small subset of ground vegetation species can be eliminated or significantly reduced in abundance by clearcutting, but that the majority of plant species are not restricted to late-successional forests and thus can survive clearcutting.[141] Those plants at risk due to clearcutting tend to be those with limited capacity for dispersal or are associated with specific microhabitat conditions such as decayed deadwood.

Forest biomass cutting in Nova Scotia

Selva found in Maine and New Brunswick that the diversity of lichen species that live on trees increases with increasing forest age.[142] Similarly, Cameron found that of 34 lichen taxa surveyed, abundance of 11 lichen taxa was greater in old-growth forests than in younger stands (2 of which occurred only in old growth), and that 25 lichen taxa were more abundant in natural forests than in managed forests (5 of which occurred only in natural forests).[143] Structural features associated with lichen abundances were tree age, presence of remnant trees, crown closure, tree volume and tree spacing. Root et al, in a study in New York, also found distinct lichen assemblages associated with large-diameter trees, and recommended managing for structural complexity and legacy trees, extending rotations and using uneven aged management systems where appropriate to ensure abundance and diversity of lichen species.[144]

17. Biomass Harvesting Impact on Coarse Woody Material

Coarse woody material was found to be lower in managed versus unmanaged stands in the Great Lake States both immediately after clearcut harvest (90% less) and 90 years after clearcut harvest (35% less); snags were also shown to be lower immediately after clearcut harvest (99% fewer) and 90 years after clearcut harvest (75% fewer).[145] Reduced coarse woody material was also found in managed forests in northern hardwoods,[146] and Acadian Forest in New Brunswick.[147] Whole-tree harvesting was shown to result in a 44-55% decrease in forest floor organic matter in a Quebec study,[148] and a significant decrease in forest floor organic matter for 64 years following harvest in northern hardwood.[149]

18. Biomass Harvesting Impact on Soil Nutrients and Acidity

Increased harvesting intensity through whole-tree harvesting has been shown to have significant effects on soil nutrient and acidity levels, as follows:

- deplete available nitrogen for 60-80 years post-harvest in northern hardwood;[150]
- increase soil acidity and decrease nutrient availability in Quebec;[151]
- decrease available potassium by 44% in Boreal balsam fir forest in Quebec;[152]
- decrease available nitrogen, phosphorus, potassium, calcium and magnesium by 500, 34, 184, 306, and 95% in red spruce balsam fir forest of Nova Scotia;[153]
- increase loss of nitrogen, reduce nutrient content in aspen trees, and reduce nitrogen and potassium in forest floor matter in Ontario mixed-wood forest;[154]
- remove 1-3% of estimated total soil capital of calcium, nitrogen, potassium and phosphorous and 30% and 85% of estimated available calcium and potassium in northern hardwood;[155]
- lead to nutrient losses on poorer soils in northern hardwoods;[156]
- result in lower Cation Exchange Capacity relative to stem-only harvest in Boreal Forest in Quebec;[157]
- potentially deplete nitrogen and calcium in dry jack pine sites in Quebec;[158]
- give short-term cause for concern of calcium depletion in study sites in Nova Scotia;[159]
- cause greater nutrient loss in white spruce stands on PEI;[160]
- cause losses of nutrients from the soil profile, increased acidification, and elevated concentrations of aluminium ions in soil solutions and streamwater in northern hardwoods;[161] and
- potentially reduce calcium over the long-term in various USA study sites including Maine and New Hampshire.[162]

As well, some soils in north-eastern USA and eastern Canada have been shown to have exceeded their acidity buffering capacity (Forest Mapping Group 2007),[163] the loss of soil calcium is proposed as a cause of red spruce die-back in north-eastern US,[164] and Thiffault et al noted that declines in nutrient availability and carbon due to both whole-tree harvesting and stem-only harvest in Boreal forest in Quebec were found to be greater than that caused by wildfires.[165] In a meta-analysis of whole-tree harvesting effects on nutrients and soil acidity in the USA, Burger and Scott noted that whole-tree harvesting depletes nutrients and increases soil acidity, and in a review of clearcutting studies in north-eastern US,[166] Ballard noted that nutrient removals in harvested timber are substantial and on some sites may influence both the amount and balance of plant-available nutrients in the long-term.[167] In a review of harvesting studies, Salonius concluded that whole-tree harvesting cannot be sustainable in the long-term.[168]

However, whole-tree harvesting was shown to not threaten soil nutrient reserves in mixed hardwood in Wisconsin on 45-year rotation,[169] to remove less than 5% of nutrient reserves in spruce-fir forest in Maine,[170] to result in no detectable change in nitrogen and carbon in a study in New Hampshire,[171] and to not give concern for short-term nutrient depletion other than for calcium in Nova Scotia.[172] In a study in red spruce and balsam fir in Maine, McLaughlin and Phillips conclude that whole-tree harvesting may be sustainable from a nutrient perspective for at least one rotation.[173]

Whole-tree harvesting was shown to result in reduced height growth of planted trees on a study site in PEI,[174] and decrease forest growth at some study sites in USA.[175]

However, in a review of long-term soil productivity sites in North America, Powers et al did not find growth reductions due to whole-tree harvesting up to 10 years following harvest (although nutrient reductions were observed).[176]

19. Summary of Biomass Harvesting Impacts on Biodiversity

The available literature is clear that increased harvesting intensity at the site and landscape level has demonstrable negative effect on various elements of forest biodiversity, including reduced abundances, reduced survival rates, altered community compositions, increased recovery times and decreased forest productivity within the time-scales studied. The effects of forest cutting on biodiversity depend on the intensity of harvesting and the nature of management actions that take place following harvesting.[177]

Numerous researchers have called attention to the impact of clearcutting, intensive forest management and / or whole-tree harvesting on forest biodiversity and productivity, and many have provided forest management recommendations to reduce the impact of intensive forestry on biodiversity and forest productivity.[178]

Some of the negative effects of increased intensive forestry associated with forest biomass fuel removal may potentially be ameliorated through (1) retaining an abundance of deadwood across a range of decay and size classes through time, (2) retaining snags and cavity trees through time, (3) leaving an abundance of fine woody material distributed on-site following a harvest, (4) retaining structural diversity, (5) retaining canopy closure to ensure suitable microhabitat for species of conservation concern that are sensitive to forest harvesting, (6) using natural regeneration techniques, (7) protecting key habitats such as watercourses and vernal pools from forest harvesting, (8) maintaining a minimum amount of suitable habitat on the landscape to counter landscape level effects of habitat loss, and (9) maintaining a minimum amount of old-forest condition at the landscape level. Some of these recommendations have been quantified; see Betts and Forbes (2005) for specific targets for coarse woody material, snags and cavity trees, and amount of old forest at the landscape level.[179]

PART V: Conclusion and Recommendations

Biomass harvesting for electricity generation is taking place in both Nova Scotia and New Brunswick with little regulatory oversight; whole-tree harvesting and near-complete removal of living and dead material from sites has occurred. The allocated biomass fuel harvest level in New Brunswick represents an approximately 20% increase in the volume of forest harvesting from the province's Crown lands, and in Nova Scotia the allowable forest biomass harvest for "renewable" energy production is an approximately 14% increase in province-wide harvesting levels.

Regulations and policy regarding renewable energy have so far failed (save for the Massachusetts exception detailed in this report) to account for the results of critical analyses of biomass fuel sources and their carbon emissions relative to fossil fuels and other energy sources. Biomass fuels are still generally considered to be carbon neutral. If the emerging science is correct, then we may be misleading ourselves as to the actual carbon and environmental benefits of biomass power generation, and undermining efforts to reduce carbon emissions due to faulty accounting.

It is apparent that none of the Maritime Provinces' renewable energy policies reflect the current understanding of the carbon emission impacts of forest biomass energy. While the carbon studies informing this report were not conducted in Nova Scotia, New Brunswick, or Prince Edward Island, the regions studied by these researchers (Massachusetts, Norway, and southern Ontario) have forest conditions similar to forest conditions in the Maritimes (i.e., temperate forests). We conclude that each of the Maritimes provinces could justifiably apply a precautionary approach to biomass energy, given the abundance of knowledge on carbon emissions and biomass energy now available.[180]

Specifically, we recommend Nova Scotia, New Brunswick and Prince Edward Island to undertake the following policy initiatives:

1. Introduce a minimum efficiency requirement comparable to Massachusetts for biomass energy projects to qualify as renewable under the provinces' various renewable energy acts;
2. Introduce a similar minimum efficiency requirement for biomass energy projects to qualify for any feed-in tariff programs (such as the already implemented COMFIT program in Nova Scotia);
3. Require biomass energy facilities to report both efficiencies attained and biomass fuel consumed and the source of the biomass fuel;
4. Restrict or prohibit whole-tree harvesting in all forestry operations to reduce impacts on forest biodiversity;
5. Introduce forest harvesting requirements on Crown lands and implement incentives on private lands to maintain or increase forest carbon storage levels; and
6. Introduce province-wide policies for no net carbon loss from land-use change through the inclusion of forest carbon modelling and full life cycle analysis of biomass energy systems.

Such policies may reduce or eliminate the current economic incentives that favour forest biomass development for electricity. The NSPI biomass facility at Point Tupper, for example, would not have qualified as renewable electricity if such policies had been in place at the time it was proposed, thus would not have been an economically viable project. The limited forest biomass resource available would be better used to heat homes (thereby replacing fossil fuel heating systems) rather than using it to produce electricity. Forest carbon storage levels would be addressed at the level of forest harvesting and land-use decisions.

Slowing or reversing the detrimental effects of forest biomass removal on forest biodiversity likely requires a combination of government regulation, financial assistance tied to improved forestry practices, and education and outreach to forestland owners and forestry workers and companies. The province of Nova Scotia has indicated an intention to address some of these issues by reducing clearcutting, regulating whole-tree harvesting, and funding education and outreach programs for woodlot owners and forestry contractors. To date, however, Nova Scotia has yet to reduce clearcutting or regulate biomass harvesting.

Forestry machinery tracts following biomass cut, with tree clump left in forest biomass clearcut, in compliance with Nova Scotia's forestry Regulations

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