REPORT

# THE STATE OF INDUSTRIAL WOOD ASH USE AS A FOREST SOIL AMENDMENT

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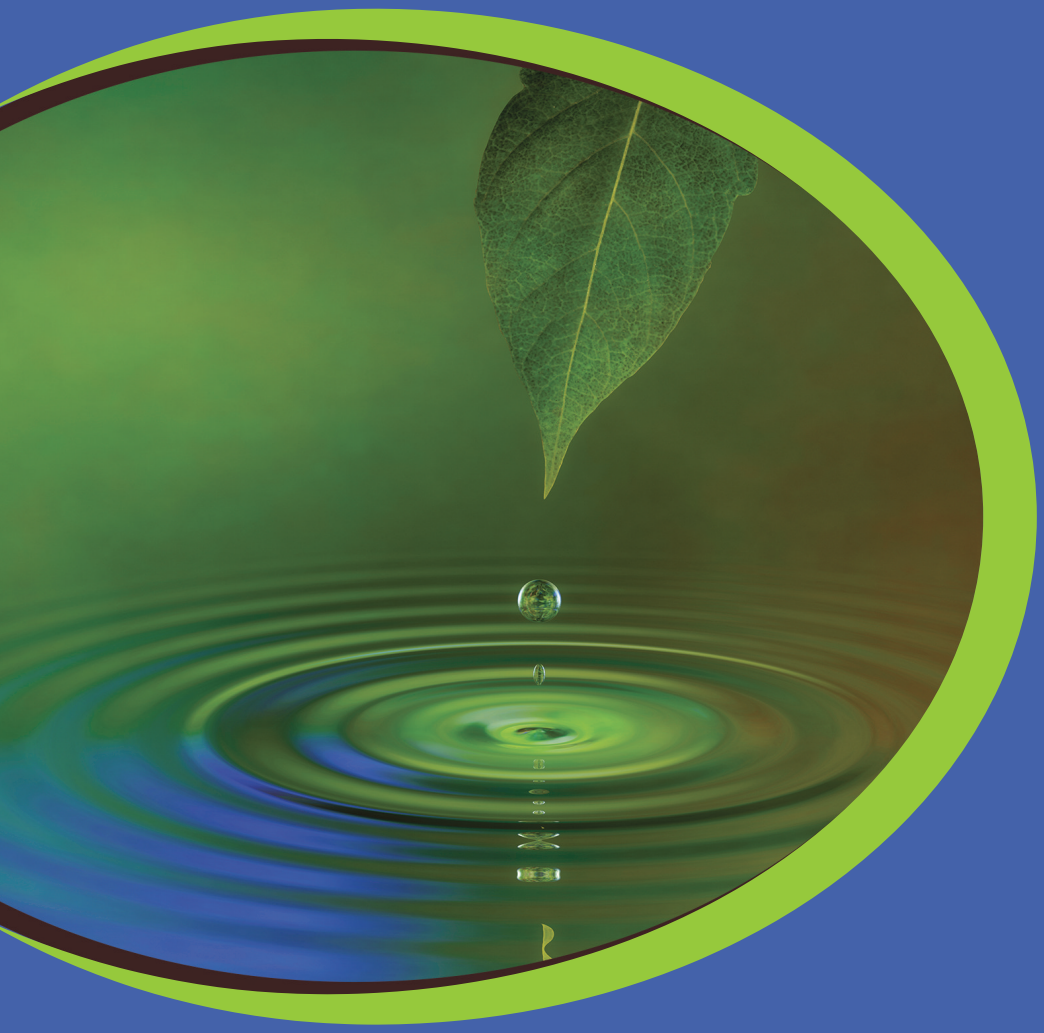

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Friends of the Muskoka Watershed

# THE STATE OF INDUSTRIAL WOOD ASH USE AS A FOREST SOIL AMENDMENT

With a focus on ameliorating calcium decline in forests affected by a legacy of acid rain in Central Ontario

K.A. Corcoran, for Friends of the Muskoka Watershed, February 2023

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# Executive Summary

In a traditional sense, industrial wood ash has predominantly been a by-product of forestry and pulp and paper mill processes. However, in recent decades, governments have placed a priority on deriving energy from renewable sources, including biomass. In this context, biomass is understood to be unused forest harvest residues (branches, bark, leaves, etc.) as well as woody fibre deemed unusable as an outcome of forest fire, disease, and insect outbreaks. This material was historically left at harvesting sites. Biomass becomes a source of energy when it is removed from the forest and burned as a source of fuel in energy plants such as the one run by Ontario Power Generation (OPG) in Atikokan, Ontario.

The increase of energy derived from biomass has two significant environmental implications. **The first is the issue of how the increase in ash by-product is disposed of**, and **the second is the nutrient sustainability of forests when forest harvest residues are removed**. While lumber, or stem wood, has been harvested from Canadian forests for decades with apparently little impact on forest sustainability, forest harvest residues contain higher proportions of essential nutrients than stem wood, and thus removal of these nutrients from the forest growth cycle has raised questions of long-term forest sustainability and soil productivity. **A corollary to this is the impact of removing forest harvest residues from forest soils that are *already* suffering from nutrient deficiencies, in particular calcium, as an outcome of acid rain.**

The environmental issue of acid rain was prominent in the 1970's, '80's and '90's. Governments and industry responded, and due to emissions controls put in place since that time, rainfall in Ontario is no longer acidic to the extent that it is cause for concern. However, **while critical damage is no longer *being* done to the environment via acid rain, forests in central Ontario, parts of Quebec, and Northeastern United States are struggling to recover naturally.** This is not unexpected given the nature of the soil, bedrock and tree species that characterize these forests. Of acute concern is the degree to which calcium in the soil has been depleted. As a result of this depletion in calcium, hardwood trees – in particular sugar maples – are not thriving. Furthermore, organisms with high calcium requirements such as snails and other mollusks that reside in neighbouring watersheds are significantly impacted, threatening eco-system balance.

**Wood ash derived from the combustion of forest harvest residues is high in calcium. It is also predominantly landfilled in Canada.**

**In recent years, governments and industry have been engaging in activities to promote the notion of a circular economy whereby waste outputs are minimized. Returning wood ash by-products to the forest would uphold the principles of a circular economy; and, where soils are nutrient-poor due to historic acid rain, it would help forests and related eco-systems recover from damage caused by human activity**.

**Despite the beneficial potential of using wood ash as a forest soil amendment (or fertilizer), the practise is virtually non-existent in North America**. Yet, governments in Finland and Sweden have promoted the recycling of biomass ashes to forest soils since the 1990's.

***Impediments***

Canadian governments, the academic community, and industry research organizations have studied the prospect of using industrial wood ash as a forest soil amendment in this country. Impediments to its use span multiple touchpoints:

- Given the potential of wood ash to be derived from feedstocks containing hazardous materials (i.e., industrial waste wood containing chemicals, or co-firing with coal**), wood ash has almost ubiquitously been classified as a waste material in regulatory regimes**, thus perpetuating the precedent of disposing of it in landfill. Both waste management and forest management are under provincial/territorial jurisdiction in Canada. Furthermore, waste management and forest management are typically managed by entirely different ministries or departments. **Regulatory pathways vary by jurisdiction, and are typically unclear and confusing.** As such, should it even be permissible,[1] parties attempting to use clean, uncontaminated wood ash as a forest soil amendment must navigate and engage in a significant amount of regulatory rigour.

- **Lack of knowledge plagues many aspects of using wood ash as a forest soil amendment**. These include:
    - **Ash dosing calibrations that respect differences in ash quality and dispersal site characteristics**
    - Practicalities and **uncertainties pertaining to supply chain development and accessibility**
    - Practicalities and **uncertainties pertaining to operational logistics and know-how**
    - Details that more acutely inform operational **cost/benefit rationale**

***Learning from elsewhere***

With regard to using wood ash as a forest soil amendment, learning can be leveraged from the practical experiences of other countries, in particular Sweden and Finland. It also can be leveraged from the initiative of some districts and/or pulp and paper mills in setting up wood ash land application programs for agricultural contexts. In the United States, several Cooperative Extension Services have encouraged the use of wood ash as a fertilizer for agricultural crops and its use for this purpose is fairly common in Maine and New Hampshire. In Canada, there are instances where ash generators such as J.D. Irving (New Brunswick and Nova Scotia) and Resolute Forest Products (Ontario) have applied for and obtained a federal fertilizer label from the Canadian Food Inspection Agency for their ash residuals. Farmers local to these ash sources are now using the ash residuals produced by these companies as crop fertilizer. In the case of J.D Irving, demand for their ash exceeds supply. The diversion of waste from landfill is a cost savings for these companies.

The province of Quebec has recognized the agricultural land application of wood ash as a recycling activity since the 1990s. Uptake of the practice was expedited by: an increase in ash disposal fees imposed on the pulp and paper industry, the cessation of government subsidies to farmers for lime fertilizer, and the increase in related agronomic information derived out of New England and elsewhere. Ash generators in Quebec can obtain fertilizer certification from the BNQ, which operates similarly to the CFIA.

[1] For example, spreading ash on Crown forest land in Ontario is strictly forbidden.

**While the practise of using wood ash as a forest soil amendment is virtually non-existent in North America,** one instance of its application on forest soils *at scale* is known and is attributed to Domtar Windsor Mill (near Sherbrooke, Quebec). They have been spreading mill residuals on tree plantations that reside on company-owned property with evident success.

***Operational Practicalities***

With the exception of the Domtar Windsor Mill example, wood ash has only been spread on forest soils in Canada on a very small scale by hand using buckets and shovels (for academic study). In-depth literature on the practicalities of spreading ash on forest soils at scale is therefore predominantly sourced from the Domtar Windsor Mill example, and from materials out of Sweden.

Outside of attaining **regulatory approvals, ensuring ash quality, dosage,** and **dispersal site characteristics are appropriate via chemical testing**, the practicalities of spreading wood ash on forest soil includes:

**Site planning:** While spreading uncontaminated wood ash on forest soil is generally deemed environmentally safe and unharmful, this is not the case when wood ash is dispersed in or near water. As such, dispersal sites must respect required regulatory distances away from watercourses and other sources of water. Site limitations must also respect proximity to public or private areas such as dwellings and roads.

**Timing of Application:** Wood ash should not be dispersed on snow or ice as it risks run-off into watercourses and other sources of water. Therefore, spreading wood ash during winter months should be avoided. Spreading wood ash during the Spring when vegetative undergrowth is accelerating should also be avoided.

**Ash preparation**: While ash can be used as a soil amendment in its original state, there are benefits to processing the ash prior to its use as a soil amendment. In all cases, processing involves wetting the ash with water which alters the chemistry of the ash and hardens it. The ash can then be crushed, granulated, or pelletized. The latter two forms of ash preparation require specific machinery to execute. Processed, or hardened ash is easier to handle, can be spread more uniformly, reduces wear and tear on machinery, reduces health and safety risks for workers, and slows the release rate of nutrients in the ash making its fertilizing effect more gradual.

**Storage**: If ash is hardened with water, it needs a period of time to 'harden.' As such, ash storage is required. Additionally, the seasonality of ash dispersal timing and ash generation may not be harmonious, therefore ash may need to be stored for periods of time.

**Methods of Spreading:** Ash can be spread by ground or by air, however, ground spreading is more common. Where forests have been previously harvested and skid rows exists, ash is typically spread using modified agricultural spreader units mounted on forestry forwarders. In mature forests, modified agricultural spreaders can be used, although productivity is comparatively reduced. An instance of a Sugar bush owner in Ontario using an ATV pulling a modified manure spreader has been noted. Spreading by ground has implications for site planning, as road accessibility for machinery becomes essential.

Ash spread over forest soils by helicopter involves loading ash into a spreading container that is suspended below the helicopter when it is airborne. Spreading by air is more logistically and economically feasible when forest treatment areas are dense and do not have existing roads or trails, or when slope and terrain are challenging. It is also advantageous when bearing capacity of the soil is a concern.

**Transportation and Equipment:** Distances between where ash is generated and dispersal site locations have significant implications on cost scenarios. This is due to the cost of transporting the ash. Cost scenarios must also account for the acquisition or accessibility of spreading equipment, as well as its transport to dispersal site locations.

**Record Keeping:** In addition to the administrative tasks of acquiring appropriate regulatory approvals and planning spreading operations, record keeping of spreading activities is often a regulatory requirement.

**Occupational Health and Safety:** Health and safety issues are not a significant limitation to the use of wood ash as a forest soil amendment; however, appropriate eye and respiratory protection (PPE) should be used when workers handle ash and skin should be protected from the possibility of exposure to wet, highly alkaline ash. Additionally, hot embers in ash are a potential fire hazard. Care should be taken to ensure ash is completely cooled prior to handling, storage, or transport.

***Motivations***

While upholding sustainability values and closing the loop in circular economies is a significant motivation to divert wood ash from landfills and use it as a forest soil amendment, additional benefits include:

- A reduction in associated landfill costs
- The potential for accelerated tree growth (dependent upon site and stand conditions) and plantation productivity
- Potential revenue from ash sales
- Increased maple syrup production

Additional environmental benefits of recycling the nutrients in ash to forest soils and promoting stronger, healthier forests include: greater volumes of carbon sequestration, and the potential for increased water absorption by trees thereby mitigating flood risks in some areas.

***Recommendations***

**Recommendations to encourage the operational use** of wood ash as a soil amendment at a systemic level include:

**Redefining or clarify the 'waste' paradigm as it pertains to wood ash**. This includes recognizing and valuing wood ash as a potential resource rather than something to be disposed of.

**Establishing a more nimble regulatory infrastructure**. While the use of wood ash as a forest soil amendment necessarily requires some form of regulatory oversight, streamlining the means to obtain regulatory approval is essential in order to encourage participation.

**Standardizing sampling and testing procedures for soil and ash assessment**. Standardizing sampling and testing procedures will streamline regulatory processes, and ease uncertainty as well as administrative burden for ash generators and ash users.

**Assess current and/or anticipated ash volumes**. Fulsome data on potential ash supply does not exist in Canada. This information is essential in order to determine operational feasibility, as well as aid in potential supply chain development.

**Provide systemic incentives to improve wood ash quality**. In Sweden, a shortfall in expected ash recycling uptake is due to lower than anticipated volumes of suitable quality ash. This is an outcome of forest fuels being co-incinerated in heating and power plants with other, cheaper forms of 'waste' wood containing toxic compounds. As biomass energy increases in Canada, ash generators may need economic incentives to ensure biomass feedstocks are not mixed with other, potentially contaminated feedstocks. This would preserve ash quality and ensure the nutrients in biomass ash can be recycled.

**Develop and refine wood ash application methods and supply chain logistics at scale.** Operational logistics and application methods – beyond buckets and shovels – need to be experientially studied and refined in Canada.

**Expand awareness, knowledge sharing activities, and breadth of collaboration**. The development of educational materials as well as broader promotion and collaboration are recommended in order to resolve the existing challenges and hurdles impeding the use of wood ash as a forest soil amendment at scale.

**Consider economic incentives to encourage engagement.** Helping industry engage in more sustainable processes and activities with incentives that are meaningful on a balance sheet may encourage interest and engagement among industry stakeholders.

**Recommendations to address nutrient-poor forest soils** and watersheds due to a legacy of acid rain on forest soils and watersheds include:

**Revisit paradigms of 'forest health' and 'sustainability**.' Government literature in Canada and Ontario consistently promotes the need to maintain and protect forest resources and related ecosystems, yet little is mentioned regarding the poor health of forests impacted by a legacy of acid rain. This is an oversight that should be addressed.

**Within the context of biomass energy development, consider a more fulsome circular economy that includes recycling wood ash to forest soils**. While promoting and developing biomass energy is a means for governments and industry to reduce reliance upon fossil fuels thereby reducing greenhouse gas emissions, addressing the beneficial use of ash by-products from biomass energy generation should not be overlooked.

**Ensure that differences in eco-zone realities pertaining to soil health and watershed health are not overlooked in policy development and forest management plans.** As biomass harvesting research and policy is developed and refined in Canada, particularly in Ontario and other provinces with nutrient-poor forests impacted by acid rain, it is imperative that the differences in forest and watershed realities between eco-zones be accounted for.

**Prioritize applied research on a catchment scale.** While the science community has done a significant amount of work studying the feasibility of wood ash as a forest soil amendment, experiments at the watershed or catena level are required in order to more thoroughly assess aquatic and other ecosystem impacts. Funding for this kind of work, especially done in the Great-Lakes St Lawrence Forest area affected by acid rain, would more demonstrably inform the issue of calcium deficiency in forest soils and watersheds presented by the Friends of the Muskoka Watershed and its academic partners. Study at a catchment scale would also provide measurable insights regarding impacts on carbon capture, flood mitigation, maple syrup production, wood production, and ecosystem health.

***Closing thoughts***

Reducing waste, replenishing what we have damaged or taken, pursuing circular economies, and ensuring our actions do not compromise the ability of future generations to meet their own needs… these ideals have become essential obligations and responsibilities that citizens, governments, and industry must collectively uphold today.

Finding optimal ways to systemically leverage the nutrient value of industrial wood ash and apply it to forest soils where biomass has been harvested and/or soils and watersheds have been damaged by human activity (historic or otherwise) requires collaboration among many stakeholders. Developing and sharing a framework of understanding around the state of industrial wood ash use is a means to foster knowledge, fuel collective awareness, and drive communication, participation, and will.

# 1.0 CHAPTER 1 Introduction

## 1.1 About this Document

This document is primarily a literature review of the state of industrial wood ash use as a forest soil amendment. It is predominantly intended for audiences in Ontario, however its scope includes Canadian, North American, and European contexts.

The focal point of this document is the logistical and practical aspects of using industrial wood ash as a forest soil amendment. While the content necessarily leaned on much that was included in academic documents both for contextual learning, as well as situational information provided as background or rationale, this document is not an academic document, nor does it attempt to review all the academic literature pertaining to industrial wood ash. In particular, it does not attempt to explain in detail:

- the benefits of wood ash as a forest soil amendment, or the status of the *science*.
- the impact of historic acid rain on forest soils and watersheds, and its remediation via wood ash

These issues are well documented elsewhere.[2]

Assessing the state of industrial wood ash use on forest soils involves delving into a complex interplay between government, industry, and environmental realities. In the case of government, it often spans

[2] **For more information about this topic**, refer to Kim. N, Watmough. S, Yan. N. (2022) - Wood ash amendments as a potential solution to widespread calcium decline in eastern Canadian forests.

two or more ministries/departments with different mandates[3] (in Ontario this would include the *Ministry of Natural Resources and Forestry*, *Ministry of the Environment, Conservation and Parks*, *Ministry of Agriculture, Food and Rural Affairs*). In the case of industry, it straddles both the forestry industry (including the pulp and paper sector), and the energy industry.

Furthermore, the environmentally beneficial use of wood ash as a forest soil amendment involves a set of parameters that is not uniform across all situations.

Given that the use of industrial wood ash as a forest soil amendment is currently quite limited in North America and elsewhere in the world, the scope of this document includes relevant aspects of industrial wood ash used in *agricultural* contexts. It also includes perspectives on the challenges and roadblocks impeding wood ash use as a forest soil amendment and provides systemic considerations to improve its use.

The following statements frame expectations regarding material compiled for this document:

> *"Information on costs, technical and logistic aspects in harvesting and wood ash recycling is scarce in existing recommendations and guidelines. [2008 context]"*[4]

> *"A large amount of research literature exists, especially on ecological consequences of forest fuel harvesting and wood ash recycling." "However, the amount of available information varies greatly among countries, as does the progress of subsequent dissemination activities. The extent to which forest fuels are harvested also vary, and proposed systems or services for wood ash recycling have not yet been established in any country [2008 context]."*[5]

A paramount impediment to the use of industrial wood ash as a forest soil amendment is its legacy as being classified as a waste.[6] However, new paradigms of sustainability, circular economies, the role forests play in combating climate change, and the environmentally imperative need to ensure forests and ecosystems are healthy, makes the rationale of appropriately recycling wood ash back to the forest self-evident.

## 1.2 Limitations and notes regarding the acquisition of material for this document

Research for this document almost singularly relied on what is publicly available via the internet. While efforts were made to uncover as much relevant material as possible, internet search functionality is limited by the following:

- **Terminology**: Language to describe industrial wood ash and/or its use as a forest soil amendment is not consistent. For example, industrial wood ash may be referred to as biomass ash, bioenergy ash, pulp and paper mill biosolids or residues, fly ash, and boiler ash. Searching

[3] Hannam. K.D, Venier. L, Allen. D, Deschamps. C, Hope. E, Jull. M, Kwiaton. M, McKenney. D, Rutherford. P.M, and Hazlett. P.W., 2018; and O'Neill. K, 2022
[4] Stupak. I, Asikainen. A, Röser. D, Pasanen. K, 2008
[5] Stupak et al., 2008
[6] **Note:** from a regulatory perspective, the definition, classification, and handling of waste, in general, is complex. Research for this document did not attempt to review the evolution of the 'waste' paradigm, or review waste policies in detail.

via the internet requires knowing what words or phrases to search for, and requires those words or phrases to be included in a relevant document's title or tags. This is often not the case. Similarly, libraries of 'resources' or contents within documents on any given website may not be searchable.

- **Corporate memberships/paywalls**: Information behind paywalls and membership logins are not searchable or accessible. Some research organizations such as FPInnovations, and NCASI (see relevant sections in Chapter 2) have published information pertaining to the use of industrial wood ash as a soil amendment but require corporate memberships to access some of this information.
- **Website architecture**: The architecture and setup of some websites makes discovering and locating documents and information difficult. For example, this author's discovery of the 'Catalogue of natural resource scientific and technical publications' on the Ontario.ca website was entirely serendipitous, and navigating to this catalogue is not intuitive.[7]
- **Language**: Internet search is language specific. Finding and accessing relevant material in other languages – in particular European languages – is a gap in the research covered by this document. While many helpful documents were available in English (and some French-language documents from Quebec were translated using Google Translate), relevant non-English material may have been missed, particularly as it pertains to Quebec, Sweden, and Finland.
- **Old or defunct websites**: While research for this document relied on internet search, a more robust and meaningful process of acquiring information was done by reviewing material referenced by others. However, in several cases, referenced documents or websites could not be located, or had become defunct.
- **Information spans 20-30 years**: While there is not a robust amount of information on the logistical and practical use of industrial wood ash as a forest soil amendment available, what does exist spans several decades. Realities change over time and are not always updated with new information. Compilation of material for this document necessarily draws from different time frames.

## 1.3 Relevance to the Friends of the Muskoka Watershed (FOTMW)

The Friends of the Muskoka Watershed (FOTMW) is a non-profit, charitable organization located out of Bracebridge, Ontario. A precis of their approved statement of purpose is:

> *"To protect freshwater watersheds using projects that: preserve, protect and restore them, improve management to adapt to major stressors, increase public understanding of their importance, and advance education through research and communicating results."*

Of paramount concern to the Friends of the Muskoka Watershed is the state of Muskoka's combined forest and watershed ecosystem, which has shown signs of significant calcium decline as an outcome of acidic atmospheric deposition (acid rain). The trees in Muskoka's forests (in particular sugar maple trees) effectively suffer from 'osteoporosis,' and as such, the organisms in the watersheds that rely on these forests for nutrients are not thriving. While this part of Canada is renowned world-wide for its lakes and

[7] https://www.ontario.ca/page/catalogue-natural-resource-scientific-and-technical-publications

forests, over 50% of the lakes in the 2EB watershed in Muskoka have calcium concentrations below the critical biological level of 1.5 mg·L−1.[8] This means that organisms in the watershed that require high concentrations of calcium to survive are diminishing.

The issue is not exclusive to Muskoka. Indeed, Muskoka is located within the *Great Lakes-St. Lawrence Forest* region of Canada which includes central Ontario as well as parts of southern Quebec and eastern Canada. Much of this forest region is prone to calcium limitation due to its history of acidic deposition and shallow soils underlain by granitic bedrock.[9]

### *1.3.1 Correcting an environmental problem caused by human activity*

The aim of Friends of the Muskoka Watershed is to fix an environmental problem affecting the region of Muskoka with a mind to share learning and knowledge in other areas of Ontario and Canada experiencing similar problems. While it is understood that 'critical loads' due to acid rain are no longer being exceeded relative to Muskoka forests and watersheds, the critically low levels of calcium in the nutrient pool will take centuries to recover naturally. As pointed out by Kim, Watmough, and Yan (2022):

> *"Some forested sites across northeastern USA and eastern Canada have begun showing signs of chemical recovery from acidification." "However, the complete recovery of forest soils from Ca depletion to preindustrial levels may take centuries because of low BC-weathering rates* [base cation weathering rates] *and is unlikely with continued harvesting in managed forests."*[10]

Scientific studies have shown that 'clean' wood ash is high in the mineral calcium, and when added to forest soils it can remediate poor tree, forest, and watershed health impacted by acid rain.[11]

The Friends of the Muskoka Watershed have been, and continue to be, engaged in this area of study. Additionally, with financial support from the *Ontario Trillium Foundation* (OTF), *Friends of the Muskoka Watershed* have been studying the feasibility of collecting residential wood ash (or non-industrial wood ash) from local and regional sources (citizens), and using it to replenish local forest soils and watersheds. A natural evolution of this activity is to explore the means to enable systemic use of wood ash as a forest soil amendment on a larger scale.

### *1.3.2 Promoting the need and benefits of replenishing forest soil nutrients with wood ash*

Canada applies sustainable forest management principles across all publicly owned forests. Publicly owned forests account for about 94% of Canada's forest land.[12]

In Ontario, about 90% percent of forest land in Ontario is publicly owned, of which 44% is managed forest. Forest management on public land is required, by law, to be managed sustainably.[13]

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[8] Kim. N, Watmough. S, Yan. N, 2022 (referencing Friends of the Muskoka Watershed; and Azan, 2017)
[9] Kim. N, Watmough. S, Yan. N, 2022 (referencing Friends of the Muskoka Watershed; and Azan, 2017)
[10] Kim. N, Watmough. S, Yan. N, 2022 (referencing Lawrence et al., 2015; Hazlett et al., 2020; Ott and Watmough 2022; Huntington et al., 2000)
[11] Kim. N, Watmough. S, Yan. N, 2022
[12] Natural Resources Canada, 2023 - Canada's commitment to sustainable forest management.
[13]Government of Ontario, 2023 – Sustainable forest management

While forests are chiefly harvested for their lumber, a by-product of harvesting lumber is biomass 'waste' in the form of tree bark, small branches, and leaves. This biomass 'waste' is very often referred to as woody debris, slash, or forest harvest residues. Until recently, forest harvesting did not typically remove this biomass 'waste' or 'woody debris' from forest sites. However, with the rise of biomass energy, the removal of unharvested woody debris – also referred to as 'whole tree harvesting (WTH) – and its use as a fuel for energy generation has gained traction. The removal of forest harvest residues has raised concerns over the regenerative abilities of forest soils and the notion of long-term sustainability. This is because: *"… it is widely acknowledged that a certain amount of woody debris plays an important ecological role on forest sites, with its removal having potential negative impacts on site productivity, soil nutrient and physical properties, wildlife habitat, biodiversity, and hydrology. Research on the effects of slash removal on forest ecosystems has been going on for more than 30 years in Canada."*[14]

Concern over the removal of forest harvest residue is corroborated by many others:

> *"Any removal of biomass from the forest removes resources that would have been available for next generation: carbon, nitrogen, mineral nutrients. There is a tipping point beyond which removal will not be compensated by natural processes…"*[15]
>
> *"Scientists in Canada and elsewhere are now looking at how much biomass in addition to trunks can be removed on an on-going basis on different kinds of sites so that guidelines can be developed for forest managers. Initial results from Canadian research indicate that the amount of additional biomass that can be removed from sites varies, depending on many factors including soil type and depth, and climatic conditions."*[16]
>
> As noted by Joseph et al., 2022: "*Biomass removal on an industrial scale can contribute to the degradation of the site productivity over successive rotations.*" It can: "*result in increased soil acidity, which may negatively impact biodiversity*".[17]
>
> *"When forest fuel is based on residual biomass, more nutrients are removed from the forest ecosystem compared to conventional stem harvesting. This has led to concern for decreased soil fertility, availability of nutrients in the soil, soil organic matter, and subsequently degraded forest productive functions."*[18]
>
> Similarly stated by the Great Lakes Forestry Centre (see *Glossary*): *"there are…concerns that biomass removal may result in excessive nutrient depletion thereby compromising long-term sustainability."*[19]

[14] Roach. J, Berch. S.M, 2014
[15] Bjurström. H, and Herbert. R, 2009
[16] Natural Resources Canada, Canadian Forest Service, 2010 - Is forest bioenergy good for the environment?
[17] Joseph. R, Diochon. A, Morris. D, Venier. L, Emilson. C. E, Basiliko. N, Bélanger. N, Jones. T, Markham. J, Rutherford. M. P, Smenderovac. E, Van Rees. K, Hazlett. P, 2022. (referencing Van Bich et al., 2018; Jacobson et al., 2014; and Reid & Watmough, 2014)
[18] Stupak et al., 2008
[19] Natural Resources Canada, Great Lakes Forestry Center - e-bulletin Issue 12, Winter 2011

When forest harvest residues are used as fuel and combusted for energy, the by-product is industrial wood ash. Uncontaminated wood ash contains nutrients and properties beneficial to soils and forests. Replacing lost nutrients from harvested soils with wood ash provides a measure of circular sustainability. However, in Ontario and most parts of Canada, the ability to spread wood ash on Crown land is highly restrictive, and the recycling of wood ash is not included in forest management plans.
The issue of soil nutrient sustainability in harvested forests is exacerbated in forests that are affected by the legacy of acid rain. Indeed, Bjurström and Herbert point out: *"The areas where the risks of acidification due to forestry operations are greatest are those that are badly affected by acidification from air pollutants."*[20]

This too is corroborated by others:

> *"The acidifying effect of forestry is compounded by acid rain. Sulphur oxides and nitrogen oxides emitted by combustion of e.g. fossil fuels precipitate and lower the pH value of soils. Acid rain is at present much less of a problem than it was e.g. twenty years ago, as steps have been taken to reduce emissions, but it will take quite some time for soil to recover…"*[21]

> *"The natural bio-geochemical cycling of Ca has been disrupted by human activities to the extent that the rate of Ca loss in many regions now exceeds that of net Ca supply. … two main drivers are acidic deposition [acid rain] and timber extraction."*[22]

With regard to Muskoka and related forests, calcium levels are so low, that should forest harvesting practices in this region – involving either clearcutting or the removal of forest harvest residues - continue without any form of nutrient replenishment, it is unlikely that these forests will be able to completely regrow. The greater Muskoka forest ecosystem will experience deleterious effects.[23]

### *1.3.3 Wood ash can make the difference*

Generally speaking, when wood ash is applied to land, it improves soil conditions and stimulates soil microbial activity. The high content of calcium in wood ash increases the pH of the soil and increases the availability of nutrients such as phosphorus, potassium, calcium, and magnesium that are essential for plant growth. Furthermore, wood ash is more soluble and reactive than ground limestone, and brings about a change in soil pH more quickly than lime. In agricultural settings, crop yields can increase significantly in areas where wood ash has been applied.[24]

Forests are complex biological environments and there has been much diligent study into the affects and appropriateness of using wood ash as a forest soil amendment. Kim. N, Watmough. S, Yan. N, (2022) reviewed the benefits of using wood ash to remediate calcium decline in eastern Canadian forests

[20] de Jong. J, Akselsson. C, Berglund. H, Egnell. G, Gerhardt. K, Lönnberg. L, Olsson. B, von Stedingk. H, 2014
[21] Bjurström. H, and Herbert. R, 2009
[22] Kim. N, Watmough. S, Yan. N, 2022
[23] Yan. N, Friends of the Muskoka Watershed, 2021 (personal communication)
[24] Lama. I (Dr.), 2022 - Fact Sheet: Wood Ash as a Soil Amendment

impacted by historic acid rain in Wood ash amendments as a potential solution to widespread calcium decline in eastern Canadian forests. [25]

As reviewed by Kim et al. (2022), wood ash on forest soils behaves similarly to that of agricultural soils in that it improves soil conditions, and increases the pH of the soil making essential nutrients (such as calcium) more available to growing trees. The anticipated benefits of this to the trees includes increases[26] in:

- Seedling production, survival, growth, and calcium concentrations in seedling stems
- Root biomass and calcium concentrations in root biomass
- Foliar (leaf) chlorophyll, and calcium concentrations in leaves
- Tree production pertaining to photosynthesis, transpiration (the process by which plants give off water vapor through their leaves), wood formation, and sap volume and sweetness
- Tree health pertaining to wound repair, freezing tolerance, drought tolerance, and crown health in mature trees

It follows then that in soils suffering from diminished calcium due to historic acid rain, the trees - and by extension the forests and forest ecosystem – function in a diminished capacity. Wood ash could adequately and safely bridge the gap and enable the organisms in these environments to return to optimal health.

# 2.0 CHAPTER 2 Contextualizing the Situation Regarding the State of Wood Ash Use

While wood ash has been generated and beneficially used for centuries, in the last century it has predominantly been treated like a waste. Yet, amid the rise of environmental, climate, and sustainability concerns, treating wood ash as a waste and putting it in landfills seems counterintuitive.

The many interconnecting parts of studying and understanding the potential of wood ash as a forest soil amendment can be complex and potentially confusing. However, for the purposes of navigating the existing paradigm, the key focal points centre around:

**The ASH itself**

- **What** is burned or combusted (also referred to as feedstock). This is sometimes enhanced or modified by what is added to the ash mixture
- **How** it is burned which impacts the chemistry of the ash

**The receiving SOIL**

- The **type of soil** and its **existing chemical state** relative to ecological requirements
- The slope and nature of the **terrain**
- **Proximity to water**/watercourses, or other sensitive areas

[25] Kim. N, Watmough. S, Yan. N. Wood ash amendments as a potential solution to widespread calcium decline in eastern Canadian forests. Environmental Reviews. 2022; 30(4): 485-500. https://doi.org/10.1139/er-2022-0017
[26] See Kim. N, Watmough. S, Yan. N. (2022), Figure 1 for associated references.

- The **purpose of the soil** re harvest expectations or ecological considerations

**Application PARAMETERs**

- Ash **dosage** and **frequency**
- **Timing** (or season) of application
- **Human safety**

In very simplistic terms, all of the above can be managed through chemical testing, best practice guidelines, and regulatory frameworks.

Respectful of limits, thresholds, and/or other required 'control' criterion, the science community consistently deems the addition of wood ash to forest soils as being safe and beneficial.[27]

## 2.1 Defining, understanding, clarifying what industrial wood ash is

When matter is combusted in the presence of oxygen (burned), ash is the material by-product that remains. The chemical nature of ash is a key determinant of whether it can be used as a beneficial soil amendment or not. It is also a key determinant in how much ash can or should be used, as well as where it can or should be used.

The chemical nature of ash is primarily determined by what is combusted and how it is combusted. (See *2.2 Wood Ash Chemistry*).

While the scope of this document is specific to industrial wood ash, in literature pertaining to the potential use of wood ash as a soil amendment, several different terms are used. To establish clarity, we define them below.

### *2.1.1 Biomass ash*

According to Natural Resources Canada: *"Biomass is a term for the biological material that comes from living or recently living plants, including trees – from their roots, trunks and branches to their bark, needles, leaves and fruit."*[28] This may include organic materials of biological origin sourced from forestry, agriculture, and aquaculture. In the literature, some definitional instances of biomass may include municipal compost.

Biomass **ash** is typically understood to be a by-product from the combustion of the following materials:

- unused forest harvest residues (see *Glossary*. See also *2.7 The Rise of Bioenergy*)
- wood salvaged after insect outbreaks, wildfires, disease, or other natural disturbance
- unused and untreated wood fibre residues from sawmills or lumber mills
- other plant-based sources such as straw, or compost

Materials in the first two categories above are referred to by the Ontario government as **forest biofibre**.[29]

[27] Kim. N, Watmough. S, Yan. N, 2022; Couch. R.L, Luckai. N, Morris. D, Diochon. A, 2020; Hannam et al., 2016
[28] Natural Resources Canada, 2023 - Forest bioeconomy, bioenergy and bioproducts
[29] Government of Ontario, 2023 - Forest biofibre allocation and use

Materials in the first three categories above are also sometimes referred to as **woody biomass**.

While ash chemistry determines the appropriateness of its use as a soil amendment, **the most ideal wood ash for forest soil amendment is ash from the combustion of unused forest harvest residues**: As stated by Emilsson (2006):

> *"…ash intended to be applied to forest land should mainly come from forest fuel, as the fundamental idea behind the application is to complete the ecocycle and make forestry and energy production sustainable over the long term. From that perspective, pure ash produced by combustion of forest fuel alone is the most appropriate to use." "Forest fuel may consist of harvest residues, timber that has no industrial use, such as biomass from neglected young forest, or industrial byproducts and waste, such as bark and sawdust."*[30]

### *2.1.2 Pulp and paper mill ashes/residuals*

The forestry industry has a long history of producing heat and power by burning timber and pulp and paper processing residues.[31] Pulp and paper mill ashes are understood to be sourced from the combustion of unused or spent wood fibre materials, as well as other mill processing residuals such as mill sludge, and wastewater treatment residuals.

The pulp and paper sector has been producing volumes of ash waste for much longer than the younger biomass energy industry. And indeed, some mills have successfully participated in, or explored, land application programs[32] (see *2.5.1 Ash Uses/Land application as a soil amendment or fertilizer*). Therefore, relevant learning can be derived from this sector and has been included in the scope of this document.

With regard to pulp and paper mill ashes, it is important to note that there are differences in the elemental compositions of the ashes resulting from the combustion of wood in combination with pulp and paper residuals.[33] This may or may not impact its appropriateness as a forest soil amendment.

### *2.1.3 Industrial waste wood ashes*

Ashes from the combustion of processed industrial wood material wastes (used in construction, or from demolition etc.) are at high risk of containing hazardous substances from chemical additives, paint, and metallic bits.

Ash that contains high concentrations of hazardous materials is <u>not</u> appropriate for use as a soil amendment.

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[30] Emilsson. S, 2006

[31] Hannam. K.D, Venier. L, Hope. E, McKenney. D, Allen. D, Hazlett. P.W, 2017 (referencing Griffin and Nyboer, 2016)

[32] Lama. I, Sain. D, 2021

[33] Elliott. A, Mahmood. T, 2006. **For additional detailed information** on pulp and paper mill residues see also Cherian. C, Siddiqui. S, 2019

In the context of this document, wood ash from construction wastes is noted simply because when it is co-fired (see *Glossary*) with woody biomass, it may contaminate the ash by-product (see *2.2 Ash Chemistry*).

### *2.1.4 Coal Ash*

While coal was derived from plant-based material millions of years ago, coal ash is not appropriate for use as a soil amendment and is not included in the scope of this document.

Wood ash differs significantly from coal ash. Ashes from coal combustion have higher concentrations of aluminum, and lower nutrient concentrations of Na, K, Ca, Mg, and P.[34]

### *2.1.5 About: Wood pellets*

Wood pellets are made of wood fibre ground down into small particles and compacted into pellets for ease of use as a combustion material. Wood pellets are predominantly used as a feedstock for biomass-based energy (see *2.7 The Rise of Bioenergy*).

The production of wood pellets is a growing industry and export in Canada. (See *2.8.1 Ash Volumes/ Wood Pellet Production*)

### *2.1.6 About: Biochar*

When organic material is combusted in the absence of oxygen (a process called pyrolysis), the by-product is called biochar.

While normal combustion consumes most of the organic carbon in the material that is burned, pyrolysis leaves much of the carbon in the biochar product. This is not necessarily detrimental to its use as a soil amendment, in fact, quite the opposite.[35] Leaving the organic carbon in can lead to a useful product for forest fertilization as the organic carbon holds moisture well.[36]

However, for purposes of amending nutrient poor soils due to historic acid rain, the key features that make wood ash an ideal amendment is its high composition of base cations (see *Glossary*), particularly calcium and potassium. The additional carbon found in biochar – while helpful in other ways - is not required to ameliorate nutrient poor soils due to acid rain. The environmental and economic upside of using wood ash rather than biochar to amend forest soils is that it is already being produced in quantities at biomass energy plants and pulp and paper plants, and is predominantly disposed of in landfills.

The production of Biochar is a fairly nascent bioeconomic industry and contributes to the circular economy[37] (see *2.6 The Cost of Landfill and The 'Circular Economy'*). The parameters and scope of this document excluded a fulsome review of biochar literature. However, the author notes that the

[34] Elliott and Mahmood, 2006
[35] Nazaroff. D, 2021. **See also** Agriculture and Agri-foods Canada, 2023 - Biochar can turn plant waste into healthy soils and improve the environment.
[36] Yan. N, Friends of the Muskoka Watershed, 2021 (personal communication)
[37] Voegele. E, 2022. See also Agriculture and Agri-foods Canada, 2023 - Biochar can turn plant waste into healthy soils and improve the environment.

emergence of the biochar market and its use as a soil amendment share common themes with this document and further study of biochar subject matter may enhance relevant learning.

## 2.2 Wood Ash Chemistry (commonly referred to as 'Ash Classification')

As previously noted, the chemistry of ash is foremost determined by the material that is combusted.

This applies to ash derived from wood fibres which can differ depending on the type of wood burned both in terms of species and tissue type.[38] Particularly notable is the fact that wood ash derived from bark and foliage has element concentrations ranging between five and 10 times greater than ash derived from stem wood.[39]

Also impacting the elemental composition of wood ash is the nature in which it is burned: "*A key factor in final ash composition is the temperature of the burn and whether the furnace [boiler] creates separate fly ash and bottom ash*."[40]

### *2.2.1 Elemental Composition*

While wood ash contains nutrients such as calcium, magnesium, potassium, and phosphorus, it also contains trace metals such as zinc, and cadmium. Indeed, perhaps the largest reticence over the use of wood ash as a soil amendment is the potential for it to contain heavy metal content that exceeds environmentally safe thresholds.

While it is uncommon, indeed extremely rare, for trace metals in wood ash to exceed regulatory allowances (other than in ash from industrial waste wood or contaminated feedstocks), it is a variable that necessarily requires diligent monitoring, and has implications for how wood ash can be used as a soil amendment.

Regardless of provincial or territorial jurisdiction, for wood ash to be used as a soil amendment in Canada it must typically be analysed to determine concentration levels of a minimum of 11 trace metals. These metals are arsenic, cadmium, chromium, cobalt, copper, mercury, molybdenum, nickel, lead, selenium, and zinc.[41] In addition to heavy metal limits, limit values may be set based on pH, acid neutralizing value, moisture content, or concentrations of potassium, dioxins and furans (see *2.2.4 About: Ash Derived from Marine Wood),* and/or polyaromatic hydrocarbons.[42]

[38] Pitman. R.M, 2006. **Of note** is Table 1 entitled *Element concentration in wood ash from various sources - % dry weight.* **For details** on the variability in macro element concentrations among bark ashes from different tree species see Elliott. A, Mahmood. T, 2006. **A robust explanation** of wood ash chemistry (nutrient content, impacts on soil pH, impacts on agricultural crop yield and crop quality) can be found in Hébert. M, Breton. B, 2008
[39] Pitman. R.M, 2006 (referencing Hakkila, 1989; Werkelin et al., 2005)
[40] Pitman. R.M, 2006
[41] Hannam et al., 2016
[42] Hannam et al., 2016

Similarly, use of wood ash as a soil amendment elsewhere in the world is very often restricted by heavy metal limits and in some cases nutrient minimums.[43] [44]

In Ontario the concentration of the 11 identified trace elements (above) are evaluated against 2 threshold levels identified as CM1 and CM2 (CM is short for 'content of regulated metals'). If all concentration levels fall **below** CM1 thresholds, then the wood ash (referred to in Ontario regulations as non-agricultural source material (NASM)) may be considered for unrestricted use.

If concentration levels of any of the metals fall **between** CM1 and CM2 thresholds, then the use of the wood ash (or NASM) is dependent upon the concentration of metal levels in the soil at the intended application site. It is also dependent upon other considerations such as minimum depth of soil to groundwater, and proximity to surface water. If any metal concentration levels **exceed** CM2 thresholds, then the wood ash or substance is considered to be a hazardous waste and therefore cannot be applied to the land.[45]

### *2.2.2 Combustion Temperature and Boiler Type*

In addition to the nature of the material combusted, ash chemistry is impacted by the temperature at which combustion occurs, and the nature of the equipment (or boiler) used. [46]

The effects of burn processes in commercial furnaces have been well researched. **For a brief description of different types of boilers and how they operate** see From Extraction of Forest Fuels to Ash Recycling: International Handbook, (Emilsson. S, 2006). **For more detailed information on the response of different soil types to ashes produced from different boilers** see Wood ash as a forest soil amendment: The role of boiler and soil type on soil property response, (Pugliese. S, Jones. T, Preston. M. D, Hazlett. P, Tran. H, Basiliko. N, 2014). **See also** Wood Ashes from Grate-Fired Heat and Power Plants: Evaluation of Nutrient and Heavy Metal Contents (Bachmaier. H, Kuptz. D, Hartmann. H, 2021).

With regard to the composition of ash containing heavy metals, Bachmaier, Kuptz. and Hartmann note:

> *"Since some of the heavy metals are volatile under the usual combustion conditions in biomass heating (power) plants, care should be taken to ensure that the combustion temperatures in the boiler are constantly high enough. An average temperature of over 750 _C, for example, reliably leads to sufficiently low cadmium contents in the bottom ash."*[47]

### *2.2.3 Fly Ash vs Bottom Ash*

The elemental composition of ash is influenced by the part of the boiler system it is retrieved from. Typically, particulates that become airborne and escape up the chimney - or stack - during the combustion process are captured by filters and referred to as fly ash (sometimes referred to as cyclone

[43] Emilsson. S, 2006 (Table 1, and Table 2).

[44] **Of note**, in Germany, wood ash used for the purpose of forest soil amendment is subject to 50% higher heavy metal limit values compared with application on farmland (Bachmaier. H, Kuptz. D, Hartmann. H, 2021).

[45] Friends of the Muskoka Watershed, 2021 – Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide (referencing Hannam et al., 2016)

[46] Emilsson. S, 2006

[47] Bachmaier. H, Kuptz. D, Hartmann. H, 2021

ash). Ash removed from the main boiler apparatus is referred to as bottom ash. Volumes of fly ash and bottom ash vary widely between boiler types, as does ash quality.[48] Concentrations of volatile metals such as mercury and cadmium are often lower in bottom ash than fly ash.[49]

### *2.2.4 About: Ash Derived from Marine Wood (wood soaked in seawater)*

Dioxins and furans can be toxic and they can be present in ash produced from the combustion of wood laden with salt. As such, ash from marine wood is not considered viable as a potential soil amendment:

> *"Coastal mills often burn wood wastes containing high concentrations of salt, which results in high concentrations of chloride in ashes as compared to inland mills."*[50]

It is notable that ash derived from wood that has been immersed in marine waters is excluded from the Code of Practice for Soil Amendments in British Columbia:[51]

In addition to ash combusted from wood immersed in oceans or salty waters, it is possible for wood ash to have high concentrations of salt if logs have been stored on landings where salt has been used for snow control. However, even when salt is present in the feedstock, dioxins may not be present in the ash if the boiler combustion efficiency and the level of operational expertise is high.[52]

### *2.2.5 About: Wood Ash and Nitrogen*

While wood ash contains an abundance of nutrients vital for tree growth and soil health, it is largely lacking in Nitrogen (N), which is an essential element for plant growth. Therefore, if wood ash is intended to facilitate tree growth or crop growth, it must be used in conjunction with other soil fertilizers to provide a complete nutrient management strategy.[53]

Contextually, nitrogen additions are not required when restoring forest soils impacted by acid rain in Ontario. Indeed these soils have an overabundance of nitrogen but an underabundance of nutrients such as calcium. This is why wood ash is an ideal soil amendment for forests suffering from a legacy of acid rain.

### *2.2.6 About: The Canadian Wood Ash Chemistry Database*

National statistics on wood ash quality have not been compiled in Canada.[54] To help fill this gap, data on the chemistry of wood ash samples from biomass boilers in Canada (sourced from pulp and paper mills

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[48] Emilsson. S, 2006; van Eijk. R.J Obernberger. I, Supancic. K, 2012
[49] Emilsson. S, 2006
[50] Elliott. A, Mahmood. T, 2006
[51] British Columbia, Ministry of Environment (Sylvis Environmental), 2008
[52] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[53] Elliott. A, Mahmood. T, 2006
[54] Lamers. F (DNVGL), Cremers. M (DNVGL), Matschegg. D (Bioenergy2020+), Schmidl. C (Bioenergy2020+), Hannam. K (CFS - Natural Resources Canada), Hazlett. P (CFS - Natural Resources Canada), Madrali. S (CANMET – Natural Resources Canada), Primdal Dam. B (Emineral A/S), Roberto. R (ENEA), Mager. R (Ontario Power Generation), Davidsson. K (SP Technical Research Institute of Sweden), Bech. N (StandardConsult ApS), Feuerborn. HJ (VGB), Saraber. A (Vliegasunie), 2018

and bioenergy co-generation facilities) has been solicited through AshNet (see *2.9.7 The State of Wood Ash Use in Canada/AshNet*):

> "*The goal of the Canadian Wood Ash Chemistry database is to provide information about the levels and variation in the element concentrations of fly and bottom ashes formed during the combustion of woody biomass, and how they compare with the trace element limits established by the Canadian Council of Ministers of the Environment (CCME).* [55]

A summary of ash qualities collected to date as well as further details can be accessed here: https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/great-lakes-forestry-centre/ashnet/canadian-wood-ash-chemistry-database/20288

## 2.3 Clarifying Purpose of Use: Amendments, Fertilizers, and 'Compensation Fertilization'

With regard to spreading wood ash on soil, in very general terms, while the application process and ash substance used may be similar or the same, the intent or purpose of its use can be somewhat different. With the literature on wood ash as a forest soil amendment spanning multiple countries and serving different purposes, we point out a few nuanced differences in terminology here:

**Amendment**

The term 'soil amendment' in relation to wood ash is commonly used, particularly in North American literature.

According to the Merriam-Webster dictionary, "an *amendment* is essentially a correction." It may also be "a material (such as compost or sand) that aids plant growth indirectly by improving the condition of the soil."

Generally speaking, our understanding from the literature is that if the intent or purpose of adding a substance to a soil is beneficial *in some way*, it is typically referred to as an amendment. The notion of 'beneficial' in this instance can mean additive or corrective/restorative.

**Fertilizer**

While a soil amendment may include 'fertilizing' qualities, a **fertilizer** is typically understood to improve plant growth and is used for that purpose. We typically think of fertilizers in relation to agricultural crops and/or silvicultural plantations.

**Compensation Fertilization**

Relative to wood ash as a forest soil amendment, a term frequently used in European literature - particularly that of Sweden - is 'compensation fertilization.' Compensation fertilization refers to adding nutrients (usually via wood ash and in some cases with other additives) to forest soils in order to compensate for the nutrients removed during forest harvest residue extraction. Compensation fertilization is also sometimes referred to as '**nutrient recycling'** or '**wood ash recycling**.'

[55] Natural Resources Canada, Great Lakes Forestry Centre, 2022 – Canadian Wood Ash Chemistry Database

An additional consideration of 'compensation fertilization,' particularly in Sweden, is **the degree to which the soil, at the time of harvest, has been impacted by the legacy of acid rain.**

## 2.4 About: Forest Management Planning, Nutrient Management, and Biomass Harvesting Policy

Forest management planning is one of the primary tools used in Canada to ensure that publicly owned forests remain healthy, vibrant, and are managed sustainably. Every forest company must have a forest management plan drawn up and approved by government before any harvesting can begin on public lands.[56]

Roach and Berch (2014) note that forest management in Canada is guided and influenced by a large collection of national and provincial commitments, strategies, legislation and regulations, procedures, guidelines, codes of practice, standards, self-regulation, and negotiated formal and informal agreements. (Indeed, they also point out that more documents of this sort were found for Ontario than for any other province or territory).[57]

It is understood that when deriving forest management policy and best practices, governments in Canada invest in and leverage scientific research.[58] As pointed out by Natural Resources Canada:

> "*Canada's forests are being studied constantly by scientists and technologists from Natural Resources Canada–Canadian Forest Service, provincial and territorial government research agencies, and academic institutions. The knowledge uncovered informs and updates forest management guidelines and regulations on a steady basis."*[59]

However, it is notable that while maintaining forest sustainability is an almost universal theme in forest management documents in Canada, nutrient management is not a common focus.[60]

Consideration for nutrient requirements within the context of 'sustainability' in Canada may include alterations in harvesting rotation length, leaving slash on site, avoiding whole tree removal, and avoiding certain sites altogether, but it typically does not include compensation fertilisation. As pointed out by O'Neill (2022), "*avoiding whole tree removal was the most prominent practice used in Canada to conserve nutrients in forest soils."*[61]

As noted earlier in this document, a large proportion of nutrients are contained in the leaves, bark, and branches (i.e., forest harvest residues) of trees. Historically, this material was considered 'unusable' and was generally left in the forest after stem wood was harvested. In the process of decomposition, nutrients in this unusable material would return and replenish the soil for forest re-growth.

However, the market for biomass-based wood pellets is growing (see *2.7 The Rise of Bioenergy* and *2.8.1 Wood Pellet Production*), resulting in increased interest in the removal of forest harvest residues (biomass) for wood pellet and energy production.

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[56] Natural Resources Canada, 2023 - Sustainable Forest Management: Forest management planning
[57] Roach. J, Berch. S.M, 2014
[58] Natural Resources Canada, 2023 - Sustainable Forest Management: Forest management planning
[59] Natural Resources Canada, 2023 - Sustainable Forest Management: Forest management planning
[60] O'Neill. K, 2022
[61] O'Neill. K, 2022

This has raised significant concern around the 'nutrient sustainability' of forest management practices relative to biomass harvesting. It is of particular concern in areas where biomass is harvested from forests that are nutrient deficient because of historic acid rain.

**Biomass Harvesting Policy in Canada**

Investigation into the policies and guidelines pertaining to forest biomass harvesting in Canada was conducted by Jean Roach and Shannon M. Berch, and published by the Province of British Columbia in 2014.[62] Compilation of the material spans 160 pages and is extensive and dense. Within that document the authors note:

> *"In general, forest management guidelines were developed for conventional logging, before biomass harvesting was done, and some may question whether or not they are adequate, given the increased level of nutrient removal, site disturbance, wildlife habitat loss, and other consequences resulting from biomass removal."*[63]

> *"A very important issue in discussions around the harvesting of woody forest biomass in Canada is whether existing policies and guidelines are adequate to ensure that it is harvested and used in a manner that will benefit present and future generations. The perception that woody biomass harvesting may stress forest resources if precautions are not taken suggest that guidelines may be needed to ensure that its harvesting is sustainable and that forest ecosystem health and site productivity are maintained."*[64]

## 2.5 Ash Uses

While the interest that the Friends of the Muskoka Watershed has in wood ash as a soil amendment specifically pertains to forests, and remediating forest soils and watersheds impacted by acid rain, ash can - and has been - used or 'recycled' in other ways.

Discussions about ash use often include the term 'beneficial use.' We note that 'beneficial use' is a relative term. While it may be beneficial to keep wood ash out of landfills and use it for other purposes, not all purposes respect the nutrient value that wood ash potentially offers.

As stated earlier in this document, wood ash has predominantly been treated as a waste both in Canada and worldwide.[65]

That said, governments in some countries in Europe (particularly in the Nordic region), have actively encouraged the diversion of wood ash from landfill. We also note that in the province of Quebec, the use of wood ash as a soil amendment is recognized as a recycling activity by the provincial government. Criteria and standards for the use of ash in Quebec were developed by the Ministere du Developpement durable, de l'Environnement et des Parcs [English translations: Ministry of Sustainable Development, Environment and Parks] in the 1990s. The BNQ (see *Glossary*) first developed a commercial standard and

[62] Roach. J, Berch. S.M. A compilation of forest biomass harvesting and related policy in Canada.
[63] Roach. J, Berch. S.M, 2014
[64] Roach. J, Berch. S.M, 2014
[65] Lamers et al., 2018. **See also** Lama. I, Sain. D, 2021.

quality requirement for ash certification in 1997 (see *2.9.2.2 Regulatory Workaround: Ash Certification as a Fertilizer or Liming Material/ BNQ*).

Apart from that, in the absence of it being a government priority, some ash generators in the United States (and a handful in Canada) – particularly from the pulp and paper sector – have explored ways to mitigate landfill costs by diverting wood ash/pulp and paper mill residues from landfill and use it in some beneficial way.

While national statistics on ash utilization have not been compiled for Canada,[66] statistics on pulp and paper mill residue use (which includes wood ash) have been compiled by Lama and Sain (2021) (referencing NCASI data… see next section, and *2.9.9 The State of Wood Ash Use in Canada/NCASI*).

Within the context of wood ash use as a soil amendment, the scope of our review was extended to include agricultural land application since the practice of applying ash on forest soils is virtually non-existent in North America.

We note that the chemical composition of the ash has an impact on its potential usage for both agricultural applications and forest applications. We also note that regulations pertaining to the use of wood ash as a soil amendment differ between agricultural and forest settings. O'Neill (2022) explains: "*This is because agricultural soils are maintained as near to neutral pH as possible during cultivation, and fertilizers are used over short periods for immediate effects. Forest soils tend to be thinner, and often more acidic, which leads to different concerns including increased levels of nitrate being leached, or increased heavy metal availability*."[67]

While land application of wood ash in North American has been predominantly for agricultural purposes we note that in the province of Quebec it has been used as a soil amendment to neutralize and rehabilitate mine tailings sites. An example includes East Sullivan Abitibi. In 2007, approximately 35,000 tonnes of ash were recycled in Quebec for this kind of usage.[68]

Beyond use as a soil amendment, wood ash can, and has been used as a cement additive, landfill cover, and road stabilizer.[69] It can also be used as a nutrient supplement in compost mixes.[70]

### *2.5.1 Land application as a soil amendment or fertilizer*

Based on 2018 data, 17.1% of pulp and paper mill boiler ash was land applied in the U.S., and 5.5% was land applied in Canada. Lama and Sain (2021) note: "*This situation likely reflects regulatory and logistical hurdles associated with developing a beneficial use program, and possibly lack of available local markets or receiving sites.*"[71]

While some ash generators (pulp and paper mills) have developed and tested various means to beneficially use wood ash/pulp and paper mill residues on their own lands, in some instances programs

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[66] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)

[67] O'Neill. K, 2022 (referencing Pitman, 2006)

[68] Hébert. M, Breton. B, 2008

[69] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
**For more information on other ash uses** see Cherian. C, Siddiqui. S. Pulp and Paper Mill Fly Ash: A Review. 2019

[70] Lama. I (Dr.), 2022 – NCASI Fact Sheet

[71] Lama. I, Sain. D, 2021

have been developed (either by local governments or ash generators themselves) to make wood ash available to local farmers. While our literature review is not likely to have uncovered all instances of such programs, examples where land application programs exist, or are likely to exist, are included in the subsequent two sections.

For more information on land application case studies see also Vance. E. D, 2000 Recycling Paper Mill By-products on Forest Lands: By-product Composition, Potential Applications, and Industry Case Studies.

### *2.5.2 Agriculture*

Clean wood ash is used in agriculture as a liming agent, as well as a fertilizer. It is often less costly than commercial fertilizers which is the primary motivator for farmers using it:

> "*Agricultural land application is by far the most common beneficial use of wood ash."*[72]
>
> "*Land application appears to be a safe, relatively simple, and economical method of ash disposal."*[73]

In the Northeast United States, as early as 1990 approximately 80% of wood ash has been land applied.[74]

> *"Land application of ash is presently [1990] being practiced in Maine, New Hampshire, Vermont, New York, and Oregon, and it appears to be a safe, cost-effective disposal method, assuming transportation distances are relatively short."*[75]

Nishio and Ersson (2016) point out:

> *"New Hampshire and Maine have well-developed commercial-agricultural ash-spreading programs. Local studies have indicated growth and yield benefits for a variety of crops. The farmers recognize the benefits of using ash compared to those of chemical fertilizers and they are willing to pay for ash and cover transport costs. The benefits of these programs include the ash generators' disposal costs being subsidized, and a reduction in the volume of ash disposed in landfills. And, the products grown on ash-fertilized farms can still be considered 'organically grown'."*[76]

#### 2.5.2.1 Land Application Programs

**United States**

- In Koochiching County, Minnesota, the Soil & Water Conservation District (SWCD) has partnered with a local pulp and paper mill to land apply wood ash from the mill to local agricultural land as a liming agent since 1997. Landowners submit paperwork to the SWCD and ash permits are processed within 10 working days. "*The Wood Ash Program, which runs 365 days per year, is a cooperative effort that has proven to be very successful since it began in the fall of 1997.*"[77] The

[72] Lama. I (Dr.), 2022 – NCASI Fact Sheet
[73] Campbell. A.G, 1990
[74] Campbell. A.G, 1990
[75] Campbell. A.G, 1990
[76] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[77] Koochiching SWCD, 2017 - Cooperative Wood Ash Program: Information Program Guide

SWCD in Beltrami County Minnesota has posted a similar service on its website, however details require direct inquiry.[78]

- The Cooperative Extension Service[79] in association with the University of Georgia encourages the use of wood ash as an agriculture soil amendment to local citizens in its document '*Best Management Practices for Wood Ash as Agricultural Soil Amendment*.'[80] Similarly, the Cooperative Extension of the University of New Hampshire does the same in its document '*Guide to Using Wood Ash as an Agricultural Soil Amendment*.'[81] See also '*Using Wood Ash on Your Farm*' from The University of Maine Cooperative Extension[82] and '*Using industrial wood ash as a soil amendment*' from University of Wisconsin Cooperative Extension.[83]

- In Maine, ReEnergy Stratton produces energy for Stratton lumber using biomass as its fuel. Surplus energy is supplied to the regional electricity grid. Beginning in 2020 ReEnergy Stratton began a new program to market its ash as a fertilizer to farmers. The company partnered with Maine Environmental to distribute the ash to about 65 local farms.[84]

**Canada**

- Incented by the increasing cost of landfill, the J.D. Irving company, which operates out of New Brunswick and Nova Scotia, began exploring the agricultural application of its wood ash residuals from biomass boiler combustion in 2003. Despite some challenges, 100% of their ash was booked for beneficial use in 2012, and by 2014 it was booked three years ahead of production. *"If J.D. Irving could produce four times as much ash, there would still be an agricultural waiting list."*[85]

  One initial challenge the J.D. Irving company faced was the cost and administrative burden of attaining provincial approval to land-apply their ash on a site-by-site basis. To alleviate this, they applied for and obtained a federal fertilizer label from the Canadian Food Inspection Agency (CFIA) in 2004.[86]

- The Resolute Forest Products company has also engaged in initiatives designed to redirect mill residues away from landfill toward land application uses. According to a press release issued by the company, in 2020 28% of pulp, paper and tissue mill residues were diverted to beneficial uses, "*most of which was land spreading*." Resolute's mill in Thunder Bay "*has distributed nearly*

[78] Beltrami SWCD, 2023
[79] The Cooperative Extension System works in partnership with the United States National Institute of Food and Agriculture, and "*translates science-based research results into language — written, verbal, and electronic — appropriate for targeted audiences. County-based educators [typically associated with a university or college] work with local citizens and interest groups to solve problems, evaluate the effectiveness of learning tools, and collect grassroots input to prioritize future research*." USDA National Institute of Food and Agriculture (NIFA), 2023
[80] University of Georgia, Cooperative Extension, 2013
[81] Saunders. O [University of New Hampshire Cooperative Extension], 2018
[82] University of Maine, Cooperative Extension, 2006
[83] Kopecky. M.J, Meyers. L, Wasko. W. [University of Wisconsin-Extension], 1990
[84] ReEnergy Stratton, 2023
[85] NEBRA [North East Biosolids & Residuals Association], 2014
[86] NEBRA [North East Biosolids & Residuals Association], 2014

*3000 metric tons of wood ash produced by [their] biomass boiler to area farmers, and continues to work with Lakehead University on developing data sets to demonstrate the beneficial use of sludge and ash applications to agricultural fields*."[87]

Similar to J.D. Irving, Resolute (Thunder Bay) applied for and received a 'soil amendment label' under the Fertilizers act for their wood ash. This was done through the Canadian Food Inspection Agency[88] (see *2.9.2.1. Canadian Food Inspection Agency*):

> *"One way companies are making ash easier for farmers to use is by registering it as a soil amendment with the Canadian Food Inspection Agency (CFIA). Ash from Thunder Bay's Resolute Forest Products, for example, is tagged as a soil amendment for pH, with an ag lime index of 23. The tag specifies best practices for storage and application, with a maximum limit of 20 tonnes per hectare over the course of a year."*[89]

### *2.5.3 Forestry*

In addition to amending soils impacted by a legacy of acid rain, wood ash on forest soils can compensate for nutrient losses due to biomass removal, and in some cases promote tree growth.[90]

Beyond academic study and activity in some European countries (particularly in Sweden and Finland – See 2.10 *The International Picture*), instances where wood ash has been used as a forest soil amendment are virtually non-existent.

Natural Resources Canada confirms: "*The application of wood ash, also called bioenergy ash, to forest soils is not a common practice in Canadian forestry."*[91]

However, a notable exception in Canada is Domtar's Windsor Mill near Sherbrooke, Quebec. A 2018 press release describes how the mill returns manufacturing by-products to the forests it manages as fertilizer. These by-products include a stabilized mixture of ash, lime, and other soil amendments to grow new sugar maple trees, and sludge from the manufacture of pulp and paper to grow hybrid poplar trees[92] (more on this topic in the section below).

## 2.6 The Cost of Landfill and The 'Circular Economy'

As society aims to 'reduce, reuse, recycle,' the definition and regulation of what is and isn't waste - and how we dispose of it - is undeniably complex. The objective of this particular document is not to review in detail how ash residues are defined and regulated worldwide. However, it is meaningful that many countries worldwide have studied and re-examined how ash residues are classified and managed, and activity exploring its beneficial use spans several decades.[93]

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[87] Resolute Forest Products, 2020 - From Forest to Farm: Resolute Reduces Waste through Land Spreading
[88] Yan. N, Friends of the Muskoka Watershed, 2022 (personal communication)
[89] Ford. R, 2019
[90] Kim. N, Watmough. S, Yan. N, 2022
[91] Natural Resources Canada, 2023 – AshNet: Why study wood ash?
[92] Domtar, 2018 - Windsor Mill's Circular Economy Reduces Waste
[93] Bachmaier. H, Kuptz. D, Hartmann. H, 2021; Bjurström. H, and Herbert. R, 2009, Campbell. A.G, 1990; Elliott. A, Mahmood. T, 2006; Hébert. M, Breton. B, 2008; Knapp. B, and Insam. H, 2011; Kopecky. M.J, Meyers. L, Wasko. W.

In the EU, in most cases when ashes are landfilled, taxes are applied on a per ton basis.[94] In some countries there may also exist a landfill ban or limitations for the disposal of biodegradable or organic waste fractions.[95] In the Netherlands, there is a ban prohibiting the disposal of fly ash in landfills.[96] These systemic restrictions necessarily force ash generators to develop or seek out alternative disposal options.

While a practical motivation for ash generators to seek out alternative disposal options is the increasing cost of landfill, the prospect of incurring costs to build new landfill sites has also been a motivator for pulp and paper mills to seek and develop ways in which to reduce waste streams.[97] Land application is among the most environmentally and economically attractive beneficial use options that these companies have explored.[98] Indeed, as early as 1990, Campbell noted that: "Land application of ash is approximately 33-66% less costly than landfilling in the Northeast [United States]." [99]

Nevertheless, as noted earlier in this document, a significant amount of industrial wood ash - clean or otherwise – is landfilled both in Canada and around the world. For context, 63.7% of pulp and paper mill boiler ash was landfilled in the U.S. in 2018, while 79.8% was landfilled in Canada.[100]

As noted by Hannam et al. (2018): "*the disposal of wood ash in Canadian landfills potentially represents a wasted opportunity to obtain greater value from forest biomass while enhancing the ecological sustainability of forestry operations.*"[101]

Nishio and Ersson (2016) provide additional perspective: "*Ash generated from bioenergy facilities is a by-product that must be put somewhere. The most common practice in Canada is to place the ash in a landfill. However, although landfilling is currently the most cost-effective method of dealing with ash by-product, bioenergy producers realize that it is not an option that will continue forever. Redirecting ash into an appropriate spreading program will help extend the lifespan of existing landfills and reduce the need for future landfills.*"[102]

### *2.6.1 Circular Economy*

According to the canada.ca website: "*In a circular economy, nothing is waste. The circular economy retains and recovers as much value as possible from resources by reusing, repairing, refurbishing, remanufacturing, repurposing, or recycling products and materials… It's about using valuable resources*

[University of Wisconsin-Extension], 1990; Okmanis. M, Petaja. G, Lupikis. A, 2017; Scheepers. G. P, du Toit. B, 2016; van Eijk. R.J Obernberger. I, Supancic. K, 2012

[94] van Eijk. R.J Obernberger. I, Supancic. K, 2012

[95] van Eijk. R.J Obernberger. I, Supancic. K, 2012

[96] van Eijk. R.J Obernberger. I, Supancic. K, 2012

[97] Gaudreault. C, Lama. I, Sain. D, 2020

[98] Gaudreault. C, Lama. I, Sain. D, 2020

[99] Campbell. A.G, 1990

[100] Lama. I, Sain. D, 2021 (referencing NCASI 2018 data)

[101] Hannam et al., 2018

[102] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction (referencing Nishio, 2013)

*wisely, thinking about waste as a resource instead of a cost, and finding innovative ways to better the environment and the economy.*"[103]

By exploring and pursuing the concept of a circular economy, Domtar's Windsor Mill is now reusing 95% of what once was considered waste by land applying their mill residues. It is estimated that this reuse will extend the life of the mill's landfill by 40 years.[104]

André Gravel, Fibre Manager at Domtar Windsor Mill provides additional perspective: *"We're working with renewable natural resources. Instead of just taking from the environment, what we're really doing is taking care of it."*[105]

Resolute Forest Products (see *2.5.2.1 Land Application Programs – Canada*) also promotes principles of the circular economy within its operations:

> "*Our approach includes recycling, energy recovery and identifying beneficial use alternatives such as agricultural land spreading, to reduce waste [including wood ash] sent to landfill*."[106]

## 2.7 The Rise of Bioenergy (aka Biomass Energy), and Why It is Relevant

Bioenergy is energy produced from renewable, biological sources such as forest biomass.[107] Biomass can be burned to create heat (direct), converted into electricity (direct), or processed into biofuel (indirect).[108] Energy created by burning biomass creates greenhouse gas emissions, but at lower net levels than burning fossil fuels like coal, oil or gas.[109]

Using biomass or unused mill by-products to generate power is not new in the forestry industry, particularly the pulp and paper sector:

> *"Many forest companies have become energy self-sufficient in the form of electricity, heat, steam and fuel. This removes the need for fossil fuels by using mill by-products (e.g., bark, sawdust and shavings) and forest biofibre to produce renewable electricity and biocrude which avoids sending material to landfills."*[110]
>
> "*Today, almost 60% of Canada's forest industry runs on bioenergy*"[111]
>
> *"Maximizing use of mill by-products reduces the need for more carbon intensive energy-based fuels and avoids unnecessary pressures on landfills. In turn, this supports the highly integrated supply chains between pulp and paper, lumber and panel mills, where one mill's by-product*

[103] Government of Canada, 2023 - Circular Economy
[104] Domtar, 2018 - Windsor Mill's Circular Economy Reduces Waste
[105] Domtar, 2018 - Windsor Mill's Circular Economy Reduces Waste
**[106]** Resolute Forest Products, 2020 - Minimizing waste and maximizing the value of resources: Resolute's 2020 highlights
[107] Natural Resources Canada, 2023 - Bioenergy from biomass
[108] National Geographic, 2023 – Biomass Energy
[109] United Nations: Climate Action, 2023 – What is renewable energy?
[110] Government of Ontario, Ministry of Natural Resources and Forestry, 2020 - Sustainable Growth: Ontario's Forest Sector Strategy
[111] Forest Products Association of Canada (FPAC), 2023 - Canada's Green Economy Grows In Canada's Forests

*(which also provides a revenue stream), supports another mill's wood supply and internal energy requirements."*[112]

However, in light of climate change issues and government targets to reduce greenhouse gas emissions[113], the scope and potential of deriving energy from biomass is expanding beyond the forestry industry. Demand for biomass derived heat and electricity is expected to continue to increase because of targets for generating energy from renewables and decreasing the emission of fossil CO2.[114]

In 2008, biomass energy made up 9.9% of the world's energy use.[115] According to World Bioenergy Association data referenced by IEA Bioenergy, energy from biomass made up 10.3% of the global primary energy supply by 2014.[116]

Renewable energy share in final energy consumption is 25% in Canada. One quarter of Canada's renewable energy is from biomass.[117]

In Canada, biomass is the third most abundant renewable energy resource. [118] The contribution of forest biomass to bioenergy production in Canada increased from 3.5% in the 1970s to 5.5% today [2019]. [119] As stated by the Canadian Council of Forest Ministers (CCFM) in A Forest Bioeconomy Framework For Canada, *"Canada contains the most biomass per capita in the world and represents 6.5 percent of the world's theoretical bioenergy potential."*[120]

Natural Resources Canada point out the following*: "To date, most of the forest biomass used to make bioenergy and bioproducts has come from the by-products of forest industry manufacturing processes. In this way, value has been added to what would otherwise be waste residues. But the increasing interest in bioenergy and bioproducts has also led to increased interest in expanding the supply of biomass available for use."*[121]

There is much debate and study around the environmental sustainability of increased biomass removal for energy/bioeconomy purposes. Review of that material is excluded from the scope of this document.[122] However, we note that the rise of bioenergy involves a dynamic confluence of several significant stakeholder groups including the Energy sector, the Forestry sector, and Government. Furthermore, it involves two highly compelling (and often conflicting) priorities: economic vitality, and environmental sustainability.

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[112] Government of Ontario, Ministry of Natural Resources and Forestry, 2020 - Sustainable Growth: Ontario's Forest Sector Strategy

[113] Natural Resources Canada, 2023 - Forest bioeconomy, bioenergy and bioproducts

[114] van Eijk. R.J Obernberger. I, Supancic. K, 2012

[115] Pembina Institute (www.pembina.org) for Ontario Power Generation (www.OPG.com), 2011

[116] Lamers et al., 2018

[117] IEA Bioenergy, 2021 - Implementation of bioenergy in Canada – 2021 update.

[118] Couch. R.L, Luckai. N, Morris. D, Diochon. A, 2020 (referencing National Energy Board, 2019)

[119] Couch et al., 2020 (referencing Natural Resources Canada, 2019).

[120] Canadian Council of Forest Ministers (CCFM), 2017 - A Forest Bioeconomy Framework for Canada

[121] Natural Resources Canada, 2023 - Forest bioeconomy, bioenergy and bioproducts

[122] **For a quick overview** see Natural Resources Canada, Canadian Forest Service, 2010 - Is forest bioenergy good for the environment? Science-Policy Notes, December 2010.

We include the following for contextual interest:

> In 2003, the Ontario government committed to ceasing all coal-fired power generation by 2014. Three coal-fired power plants were closed, and the Atikokan and Thunder Bay plants were converted from coal to biomass. The Thunder Bay plant was subsequently closed in 2018.[123] The Atikokan plant uses 90,000 Mg of wood pellets per year[124] and is still in operation. The Atikokan Generating station is currently the largest 100% biomass-fuelled plant in North America.[125]
>
> In 2022 the Ontario Government released its inaugural Forest Biomass Action Plan: *"This action plan was developed in collaboration with a Forest Biomass Action Plan Working Group (the Working Group) comprised of partners from across the forest biomass supply chain. The action plan highlights Ontario's forest biomass advantages, recognizes challenges and seeks to identify means to increase the use of forest biomass. Valuable insights from the Working Group members highlighted the importance of bioenergy to existing forest product supply chains. Maintaining and transitioning the province's existing bioenergy infrastructure will create a foundation for future forest biomass investment opportunities and increase support for Ontario's forest dependent communities."*[126]
>
> *"Ensuring that the forest industry squeezes the maximum value out of every tree harvested is now seen as key to building and maintaining Canada's international competitiveness."* [127]

### *2.7.1 More Biomass Energy means More Ash is Produced*

Trends in energy sourced from biomass implies that sizeable amounts of ashes are – or will be - generated. It is estimated based on 2014 data, that 10 million tons of ash are produced globally from electricity production, with heat-only production generating additional quantities.[128]

Yet, as pointed out by Lamers et at.,: *"On a world wide level, no or a limited number of guidelines with best practices have been developed in the field of ash management."*[129]

Hannam et al. provide perspective: *"The prospect of industrial-scale forest biomass harvesting has raised concerns about possible negative impacts on forest biodiversity, habitat quality, site productivity, soil nutrient cycling and hydrology. To date however, less attention has been paid to the growing volume of wood ash generated as a by-product of bioenergy production."*[130]

Given that wood ash derived from the combustion of biomass feedstock retains almost all of the essential nutrients and minerals that soils need to grow a forest (nitrogen excepted), it follows then that a 'complete' execution of the circular economy – one that incorporates ecological considerations and

[123] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[124] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[125] Ontario Power Corporation, 2023 – Biomass Power
[126] Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, 2022 - Forest Biomass Action Plan
[127] Natural Resources Canada, 2023 - Forest bioeconomy, bioenergy and bioproducts
[128] Lamers et al., 2018
[129] Lamers et al., 2018
[130] Hannam et al., 2017 (referencing Lattimore et al. 2009, Thiffault et al. 2011, Roach and Berch 2014)

promotes environmental sustainability – is to return biomass ash to the forest instead of putting it in landfills.

Pettersson, Björnsson, and Börjesson (2020) similarly state: *"A prerequisite for the long-term sustainable increased use of logging residues in the biobased economy is closing the material loop by recycling the wood ash from incineration to the forest, to avoid reduced forest productivity.*[131]

## 2.8 Ash Volumes – Perspectives (Canada)

As noted in Options for increased use of ash from biomass combustion and co-firing (IEA Bioenery: Task 32, 2018) "*national statistics on ash production in Canada have not been compiled*."[132] However in 2013, 420,000 Mg[133] (dry) of ash were produced in Canada sourced from **pulp and paper mills only**. Of this amount, 37% was redirected from landfill for beneficial use. [134]

Additional ash volume statistics included in the IEA Bioenergy report provide a few provincial snapshots:

- Alberta (wood ash, 2015): 59 639 Mg (dry) (referencing Dinwoodie.G, 2016)
- British Columbia (uncontaminated forest biomass ash, 2014): 100,849 Mg (dry) (referencing Nishio, 2016)
- Quebec (wood ash, 2007): 300,000 Mg (**wet**) (referencing Hébert and Breton, 2008)

Further details on ash volumes and related usage in Quebec were provided in Recyclage agricole des cendres de bois au Quebec – Etat de la situation, impacts et bonnes practiques agro-environmentales:[135]

> [English translation] "*Quebec produced 300,000 mt of ash in 2006. Two-thirds came from pulp and paper mills, and the other third from power co-generation plants, as well as sawmills and other industries. In 2007, 150,000 tons of ash (nearly half of the total) were recycled as fertilizing materials. Of this amount, 54% was used for agriculture, and the rest for the revegetation of degraded sites, the manufacture of compost, composting and other purposes. The majority of ashes not recycled were landfilled.*"[136]
>
> "*The quantities recycled specifically for agriculture increased 80% between 1999 and 2007, benefitting about 250 farms*."[137]

In 2021, there were 35 pulp and/or paper mills in Canada generating biomass based thermal or electrical energy. The provincial breakdown of those mills are as follows:

[131] Pettersson. M, Björnsson.l, Börjesson. P, 2020 (referencing de Jong et al., 2017; Drott et al., 2019)
[132] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[133] The Mg symbol refers to a metric tonne. https://www.nist.gov/pml/owm/si-units-mass
[134] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction (referencing Elliot and Mahmood 2015)
[135] Hébert. M, Breton. B, 2008
[136] Hébert. M, Breton. B, 2008
[137] Hébert. M, Breton. B, 2008

| Province | # of Pulp and Paper Mills Producing Biomass-based Thermal or Electrical Energy |
|---|---|
| British Columbia | 13 |
| Alberta | 5 |
| Manitoba | 1 |
| Ontario | 2 |
| Quebec | 8 |
| New Brunswick | 5 |
| Nova Scotia | 1 |

Source: 2021 Pulp, Paper, & Bioeconomy Map, Pulp & Paper Canada

The two mills based in Ontario are: Aditya Birla Group - Terrace Bay, and Resolute Forest Products – Thunder Bay.[138]

With regard to ash produced by the two OPG biomass plants (Atikokan and Thunder Bay), the following was quoted in the Options for increased use of ash from biomass combustion and co-firing report from IEA Bioenergy (2018): *"The mass of biomass ash produced at the Atikokan and Thunder Bay Generating Stations represents <1% of the mass of pellets combusted (i.e., <975 Mg ash per year)."*[139]

Ash by-product from the Atikokan station is currently disposed of in municipal landfill as specified in the Environmental Certificate of Approval (ECA) under which the station currently operates.[140] Due to the 'small' volume of ash produced at the Atikokan station, "*there is currently no significant economic driver to find an alternative use for this material*." While an ECA specifies that the ash must be disposed of in a municipal landfill, "*an amendment to the ECA could be requested if an environmentally safe and economically viable alternative use for the ash were identified*."[141]

### *2.8.1 Wood Pellet Production*

The production of wood pellets (which are used to fuel electricity and heating plants) is a growing industry and export in Canada. Most Canadian wood pellets are exported to other countries, and from 2012-2016 exports increased 73%.[142] According to a report filed with the United States Department of Agriculture (USDA) FAS GAIN:[143] Canadian wood pellet production was expected to reach 3.8 million metric tonnes in 2021 up from 3.5 million metric tons in 2020. Exports comprised 2.901 million metric tonnes in 2020 (a little over 80%). While domestic use of wood pellets for heat and power generation

[138] Pulp & Paper Canada, 2021
[139] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R). Per Pitman. R.M, 2006 "*the commercial burning of wood generates up to 1 per cent ash by weight."*
[140] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[141] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[142] Canada Energy Regulator [Government of Canada], 2017 - Market Snapshot: Canadian wood pellet exports grew 46% between 2015 and 2016
[143] United States Department of Agriculture, Foreign Agriculture Service, Global Agriculture Information Network

remains limited, it is expected to grow. Canada consumed an estimated 430,000 metric tonnes of wood pellets in 2020. This was expected to grow to 450,000 metric tonnes in 2021.[144]

As domestic use of wood pellets grows, it follows then that ash produced from wood pellet use will also grow.

## 2.9 The State of Wood Ash Use in Canada

Other than for academic and research purposes, there is scant literature in Canada pertaining to – or mentioning - the use of wood ash as a soil amendment in this country.

As pointed out by Hannam et al., in AshNet: Facilitating the use of wood ash as a forest soil amendment in Canada:

> *"Wood ash is often treated as a waste material in Canada and landfilled. However, this situation is changing: in 1995, 84% of the ash produced in power and recovery boilers at pulp and paper mills was landfilled; by 2002, 78% of this was landfilled and in 2013, only 63% was landfilled. Nevertheless, wood ash disposal rates vary considerably among provinces. In Québec, about 50% of approximately 300 000 Mg of wood ash produced in 2005 was landfilled, and in Alberta, some 51% of approximately 60 000 Mg of wood ash produced in 2015 was landfilled. By contrast, some 96% of about 235 000 Mg of wood ash produced in British Columbia in 2014 was landfilled."*[145]

While instances of wood ash being used as an agricultural soil amendment in Canada are evident (see *2.5.2.1 Ash Uses/Agriculture/Land Application Programs - Canada*), instances of wood ash being used as a *forest* soil amendment are practically non-existent in literature. The exceptions would be its use as a forest soil amendment by Domtar's Windsor Mill (near Sherbrooke, Quebec) on its own private lands (see *2.5.3 Ash Uses/Forestry*), and the AshMuskoka program under development by the Friends of the Muskoka Watershed in Muskoka, Ontario.[146]

### *2.9.1 Regulatory Situation*

As pointed out in the CCFM's Forest Sector Innovation in Canada report, "*The department of Natural Resources Canada is the federal authority on matters pertaining to Canada's forests through the Canadian Forest Service (CFS)."*[147] That said, regulatory matters pertaining to forest use fall under provincial or territorial jurisdiction. *"Canada's provinces and territories own the majority of the country's forests and are thus accountable for the sustainable development of these resources."*[148]

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[144] Voegele. E, 2021 - Canadian wood pellet production to reach 3.8M metric tons in 2021
[145] Hannam et al., 2017 (referencing Elliott and Mahmood, 2006; Elliott and Mahmood, 2015; Hébert and Breton, 2009; Dinwoodie, 2016; Nishio 2016)
[146] Friends of the Muskoka Watershed, 2023 – About AshMuskoka
[147] Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation in Canada 2015, White Paper: Opportunities for the Canadian Council of Forest Ministers
[148] Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation in Canada 2015, White Paper: Opportunities for the Canadian Council of Forest Ministers

The use of wood ash as a **forest** soil amendment is hampered in Canada and elsewhere around the world[149] often because of its legacy as being classified as a waste in regulations. While clean wood ash has been deemed by science to be 'safe' in most situations, for reasons of environmental safety and prudence, it necessarily requires some measure of regulation or oversight.

Hannam et al. (2018) points out: "*At present, none of the provincial or territorial policies and regulations that apply to forestry operations in Canada encourages soil applications of wood ash*."[150]

In addition to forest resources being managed at the provincial or territorial level, the handling of waste is also under provincial/territorial jurisdiction in Canada. However, within provincial/territorial jurisdictions, they each are typically handled by different ministries or departments. For example waste management is often handled by 'ministries of the environment', whereas forest management is often handled by 'ministries of natural resources, or forestry'. In some instances (such as in Ontario), the notion of using a 'non-agricultural source material' (NASM) (i.e., wood ash) as a soil amendment involves a third government ministry, Agriculture, Food, and Rural Affairs.[151]

The process and requirements to gain regulatory approval to use wood ash as a forest soil amendment - or even an agricultural soil amendment - differs widely by province, and in many cases clear guidelines are not in existence specifically for this purpose.[152]

In addition to regulatory processes differing by province, Nishio and Errson point out that *"local areas may also have requirements that are further to federal or provincial legislation, and these can be quite specific. For example, some local seasonal activities or wildlife and community/recreational issues may restrict timing of ash applications."*[153]

Considering all of the above, approval processes are complex, time consuming,[154] and potentially costly.[155]

The Canadian Forest Service, operates several research centres across Canada including the Great Lakes Forestry Centre (GLFC) out of Sault Ste. Marie, Ontario (see *Glossary*). In 2016, the GLFC issued a report synthesizing regulations and guidelines across Canada for the use of wood ash as a soil amendment in Canadian forests. The report provides a robust overview of regulatory processes on a province-by-province basis. As pointed out in that document *"regulations that were developed for other materials*

[149] For regulatory perspectives in other countries, see Lamers et al., , 2018

[150] Hannam et al., 2018

[151] **The author notes** that government ministry names and portfolios change and evolve over time. Unless one is aware of these evolutions, following threads of policy changes and history (especially when acronyms are used) can be somewhat contextually challenging or confusing. For example, in Ontario, the '*Ministry of the Environment (MOE)*' has changed six times since 1972: from 1993 to 1997, and again (briefly) in 2002, it was changed to *Ministry of the Environment & Energy (MOEE)*, in 2014 it was changed to *Ministry of the Environment & Climate Change (MECC)*, and in 2018 it was changed to *Ministry of the Environment, Conservation and Parks (MECP)*.

[152] Hannam et al., 2016

[153] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction

[154] Hannam et al., 2018 (referencing Hannam et al., 2016)

[155] **Costs may include** testing, application fees, administration, and in some cases fees for required services from qualified professionals.

*(e.g. biosolids, compost, hazardous waste) are typically also applied to wood ash, and these can be confusing and difficult to interpret."*[156]

Paul Hazlett of the GLFC made the following additional comments in a presentation entitled Recycling bioenergy ash in forests: hiccups and hurdles (webinar):[157]

> *"…there really isn't a lot of clear definition about applying wood ash. Wood ash is usually put in some kind of category in terms of how it can be applied to forest sites." "In some cases ash is considered a fertilizer, in some cases a waste product, in some cases a 'non-agricultural source material' [among other things]… in terms of all these different formal regulations across the country, there could be up to 30-50 difference classifications for ash."*
>
> *"I know from personal experience and talking to people in industry and in government that are looking to use ash, that they find it is very difficult to understand the regulations on how it might be applied to a forest site."*

While guidelines for the specific use of wood ash as a soil amendment do not exist for many provinces in Canada, wood ash is included or mentioned in soil amendment guidelines in the provinces of Alberta, British Columbia, and Quebec as follows:

- Alberta: Standards and Guidelines for The Use of Wood Ash as a Liming Material For Agricultural Soils
- British Columbia: Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice.
- Quebec: Guide sur le recyclage des matières résiduelles fertilisantes : Critères de référence et normes réglementaires [Guidelines for the Beneficial Use of Fertilising Residuals].[158]

Within an agricultural context, Lama and Sain point out that while approval processes differ by jurisdiction, "*requirements regarding ash handling and storage, transportation, and recommended land application practices are similar across North America*."[159]

### *2.9.2 Regulatory Workaround: Ash Certification as a Fertilizer or Liming Material*

As pointed out by Hannam et al. (2016), *"the provincial/territorial approval process can sometimes be streamlined if the ash has received certification as a fertilizer or liming material from the Canadian Food Inspection Agency (CFIA) or the Bureau of Normalisation du Quebec (BNQ)." This is because "fertilizers and liming agents are commonly used as soil amendments and the guidance surrounding their use is well developed.*" Examples of this are noted in 2.5.2.1 *Ash Uses/Land Application Programs – Canada* of this document.

[156] Hannam et al., 2016
[157] Hazlett. P, 2016
[158] The most recent edition of these guidelines (2015) are not available in English. For this report, material was reviewed in English via 'Google Translate'
[159] Lama. I, Sain. D, 2021

#### 2.9.2.1 Canadian Food Inspection Agency (CFIA)

Ash is listed as a 'primary supplement material' by the Canada Food Inspection Agency. Supplements are defined as 'products other than fertilizers that improve the physical condition of the soil or aid plant growth or crop yield'. Most supplements need mandatory pre-market assessment and registration before importation or sale in Canada. They are regulated under the Fertilizers Act.

Designated by 'kind of ash', the general description of ash by the CFIA is as follows: *Non-combustible alkaline residue remaining after the combustion solely of crop residue, wood or any combination thereof, that have not been transported in salt water or subjected to chemical treatment outside of acidification, and having a calcium carbonate equivalent (neutralizing value) ranging from 40 to 80% (Cendre).*[160]

Registration of a supplement with the CFIA requires detailed chemical analysis as outlined in the Guide to Submitting Applications for Registration under the Fertilizers Act. Further application requirements and expectations are detailed in the Guide.[161]

#### 2.9.2.2 BNQ (Bureau de normalization du Québec)

In Quebec, one can obtain certification regarding wood ash quality (as a liming material) from the Bureau de normalisation du Quebec (BNQ).[162]

The BNQ is mandated by the government of Quebec to lead standardization activities in that province. The organization is recognized by the Standards Council of Canada.

For a summary of the main criteria of the BNQ standard for applying wood ashes and other woody residues (2008/agricultural context) see Hébert. M, Breton. B, 2008.

Among other things, the BNQ has developed commercial standards and a certification regime for fertilizers. This includes 'liming materials from industrial processes, which includes 'calcium or magnesium amendments' (ACMs). Wood ash falls under this category.[163]

### *2.9.3 British Columbia*

Among all the provinces and territories in Canada, British Columbia harvests the largest amount of lumber by volume (38%).[164] British Columbia also has 'the highest forest use intensity rates of all provinces that are harvesting at a sustainable rate, and harvests about 91 per cent of its annual allowable cut.[165]

[160] Canadian Food Inspection Agency, 2023 – List of Primary Fertilizer and Supplement Materials
[161] Canadian Food Inspection Agency, 2020 - Guide to Submitting Applications for Registration under the Fertilizers Act (New Regulations). 2020.
[162] Hannam et al., 2016
[163] Bureau de normalisation due Quebec, 2022 - Norme BNQ 0419-090 Amendements minéraux – Amendements calciques ou magnésiens provenant de procédés industriels
[164] Natural Resources Canada – Statistical data, 2020 : https://cfs.nrcan.gc.ca/statsprofile/
[165] The Conference Board of Canada – Use of Forest Resources (referencing 2013 data)

British Columbia also has the highest number of pulp and paper mills producing biomass-based thermal or electrical energy[166] (see *2.8 Ash Volumes – Perspectives (Canada)*).

As pointed out in an article by Rutherford, Massicotte, Chisholm, and Jull (2016): *"… although bioenergy systems are generally considered green and environmentally sustainable, they generate substantial quantities of wood ash. Such industrial wood ashes have been historically treated as waste in British Columbia and the standard practice has been to bury them in landfills or when possible, as concrete additives."*[167]

Wood ash as a soil amendment for agriculture and forests is being studied in British Columbia (out of UNBC with funding support from industry and the federal government (via NSERC, Natural Sciences Engineering Research Council of Canada).[168]

Research for this document otherwise did not uncover any instances of land applied wood ash outside of academic trials in BC.

### *2.9.4 Ontario*

In Ontario, Crown forest is licensed out to forestry companies under strict 'forest management' contracts. These contracts do not require nutrient amendments, nor do regulations permit the use of wood ash on public land. Since wood ash is considered a waste product in Ontario, it is not allowed to be spread in forests under the Nutrient Management Act.[169]

As noted earlier in this document, Ontario is home to the largest 100% biomass energy generating station in North America. All of the wood ash produced by this generating station is currently landfilled.

With regard to the sustainability of biomass harvesting, the province has engaged in related research for several decades through its 'Long-term Soil Productivity Research' (section 2.9.4.1 below). A Bioeconomy Technical Working Group (section 2.9.4.2 below) is associated with this work, among other things.

#### 2.9.4.1 Long-term Soil Productivity Research

Prior to 1994, Ontario's principal Forestry Act was the Crown Timber Act which largely focused on "timber" management. This Act was replaced in 1994 with the Crown Forest Sustainability Act (CFSA) which has been regarded as "*a foundational piece of legislation that required forest license holders to 'sustain diverse and healthy forests for the social and economic benefit for the people of Ontario*.'"[170] As an outcome of a Forest Class Environmental Assessment (EA) for timber management on Crown Lands that was conducted just prior to the introduction of the CFSA, the Ontario Ministry of Natural Resources was mandated to establish long-term research trials to evaluate the effects of full-tree harvesting on long-term soil productivity. [171]

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[166] Pulp & Paper Canada, 2021 – 2021 Pulp, Paper, and Bioeconomy Map
[167] Rutherford. P.M, Massicotte. H.B, Chisholm. C.E, Jull. M. J, 2016
[168] Rutherford. P.M, Massicotte. H.B, Chisholm. C.E, Jull. M. J, 2016
[169] O'Neill. K, 2022
[170] Morris.D.M, Fleming. R.L, Hazlett.P.W, 2020
[171] Morris.D.M, Fleming. R.L, Hazlett.P.W, 2020

At some point during the evolution of the Ontario LTSP (long-term soil productivity) project, the study of the effects of wood ash application on full-tree harvested sites was incorporated into site experiments (see *2.9.7 The State of Wood Ash Use in Canada/ AshNet*). It is unclear how much of this research extends to impacts on watersheds, or whether considerations for acid rain impacts (such as that in the Great Lakes-St. Lawrence Forest) are included in the research.

#### 2.9.4.2 Bioeconomy Technical Working Group (BETWG or TWG)

At the time that Ontario was establishing its LTSP research trials, the federal government, through the Canadian Forest Service was administering the Energy from Forest Biomass program funded by the Interdepartmental Panel on Energy Research and Development. This program was aimed at generating sufficient knowledge and technology to realize a marked increase in the contribution of forest biomass to Canada's energy supply.[172]

In response to these federal and provincial initiatives, a joint federal-provincial Sustainable Productivity Technical Working Group was formed in 1992 consisting of key research scientists from both the Ontario Ministry of Natural Resources (OMNR), and the Canadian Forest Service (CFS). Their mandate was to establish long-term research trials to evaluate the effects of full-tree harvesting on long-term soil productivity (LTSP). [173]

By 2009 this working group had been renamed the Bioeconomy Technical Working Group and its membership had expanded to include forest managers and senior policy advisors. An objective of the group is to identify and consider options to address the most relevant science and policy needs of Canada and Ontario.[174] Additional objectives include identifying bioeconomy science and knowledge-sharing opportunities and developing additional collaborative initiatives.[175] It is unclear how much of the Working Group's focus includes the issue of wood ash.

### *2.9.5 Quebec*

Wood ash was managed as a waste in Quebec up until the 1980's and 1990's. At that time, new regulations were imposed on the pulp and paper industry that increased ash disposal cost. Additionally, the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation* (MAPAQ) (English translation: Ministry of Agriculture, Fisheries and Food) stopped subsidizing lime use in agriculture. These two phenomena, as well as agronomic studies done in New England and elsewhere, contributed to the subsequent interest for ash spreading in Québec since that time.[176]

[172] Morris.D.M, Fleming. R.L, Hazlett.P.W, 2020
[173] Morris.D.M, Fleming. R.L, Hazlett.P.W, 2020
[174] Natural Resources Canada, Great Lakes Forestry Center - e-bulletin Issue 14, Summer 2011; Morris.D.M, Fleming. R.L, Hazlett.P.W, 2020; Puddister. D, Dominy. S.W.J, Baker. J.A., Morris. D.M, Maure. J, Rice. J.A, Jones. T.A, Majumdar. I, Hazlett. P.W, Titus. B.D, Fleming. R.L,Wetzel. S, 2011
[175] Natural Resources Canada, Great Lakes Forestry Center - e-bulletin Issue 12, Winter 2011
[176] Hébert. M, Breton. B, 2008

Guidelines for the land application of wood ashes were developed in Quebec in the 1990s. As noted earlier, Quebec has recognized the use of wood ash as a soil amendment as a recycling activity for some time.[177]

In *Guide sur le recyclage des matières résiduelles fertilisantes : Critères de référence et normes réglementaires – Édition 2015* [Guide to the recycling of fertilizing residual materials: Reference criteria and regulatory standards],[178] wood ash is identified as a fertilizing residual material (MRF) and is included in a category referred to as 'calcium or magnesium amendment' (ACM). Within the Guide, a section exists specifically for 'Spreading on Forestry Soil.' However, the guidelines in this Forestry section are basically intended for tree plantations that have commercial value.

The guide mentions that: "*To promote the uptake of applied nitrogen, reduce nitrogen losses, and promote balanced tree growth, the silvicultural recommendation must also take into account the management of P and K, and aim for an optimal soil pH*." But there is no mention of using wood ash – or any other amendment or fertilizer - to correct for calcium deficiency.

There is a separate (but related) guide in Quebec specifically for the use of MRFs for *the restoration of the vegetation cover of degraded places*:[179] The objective sought in this guide is: *"to promote the establishment and maintenance of vegetation by correcting deficiencies in soil properties caused by human activities* [English translation]." However, the concept of 'degraded places' in the document "*concerns a surface of soil characterized by a significant deficiency in supporting vegetation, following various works, such as land after the exploitation of a quarry, a sandpit, mine, etc.* [English translation]"

> Per the guide: *"Restoring the vegetation cover of a degraded place consists of improving the chemical, physical or biological properties of a soil surface, in order to promote the establishment and maintenance of vegetation in the short, medium and long term.* [English translation]" Also: *"The improvements made to the site must be carried out in such a way as to preserve the quality of the soil required by the vocation of the site and to maintain the current and future uses of surface water and groundwater.* [English translation]"

There is no mention of nutrient-poor sites due to acid rain in the guide despite the fact that the area of forests in Canada impacted by historic acid rain (and are consequently calcium-deficient) extends into parts of Quebec. We also note that calcium deficiency in sugar maples reduces sap productivity, and that the maple syrup industry in Quebec is notably meaningful for that province. Kim et al. (2022) add perspective: *"Improving the health and vigor of sugar maple stands, which have been disproportionately affected by acidification and Ca decline, also has substantial economic benefits given that maple syrup production is a major industry in eastern Canada. Nearly three-quarters of the world's "liquid gold" is produced on average each year in Quebec alone, representing almost $1 billion (CAD) of the country's gross domestic product."*[180]

Hébert and Breton, (2008) summarized the regulatory process in Quebec as follows [English translation]:

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[177] Hébert. M, Breton. B, 2008

[178] Hébert. M, 2015- Guide sur le recyclage des matières résiduelles fertilisantes : Critères de référence et normes réglementaires – Édition 2015

[179] Burelle. S, Beaulieu. R, St-Laurent. S, 2005 - Guide sur l'utilisation de matières résiduelles fertilisantes (MRF) pour la restauration de la couverture végétale de lieux dégradés: Critères et exigences

[180] Kim. N, Watmough. S, Yan. N, 2022 (referencing Producteurs et productrices acericoles du Quebec, 2021)

The quality control or regulation of wood ash use as an agricultural amendment is managed through a combination of the following three mechanisms in Quebec:

- Certification of ash conformity by the BNQ (see *2.9.2.2 BNQ)*
- Annual certificate of authorization (CA)[181] for spreading by the Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) (English translation: Ministry of Sustainable Development, Environment and Parks)
- Project notice by an agronomist, sent to the MDDEP, with quality control by an accredited sampling firm

### *2.9.6 Atlantic Canada*

Beyond specifics provided in Hannam et al. (2016) in Regulations and guidelines for the use of wood ash as a soil amendment in Canadian forests, limited additional information was discovered in the literature for the Atlantic provinces. We include a few notes indicating degrees of government interest and activity:

**Nova Scotia**: "*In Nova Scotia, the provincial government encourages the use of wood ash as a fertilizer and liming agent on farmland by subsidizing the transportation costs of agricultural producers; the practice has become so popular that supplies of available wood ash often run out.*"[182]

**New Brunswick**: In 2021, the government of New Brunswick announced it was investing over $100k in an initiative that would: "*identify and analyze local, high-quality and affordable industrial ash that could be used by farmers to improve soil fertility, soil health and productivity*." Included among those by-products was wood ash.[183]

In an article published in an Ontario agricultural publication about the popularity of industrial wood ash in the Maritimes, a New Brunswick farmer is quoted as saying "*there's a waiting list for it*." The article goes on to say that 400,000 tonnes of wood ash have been used by farmers in the Atlantic provinces since 2015 (no source provided). Also, according to the article, New Brunswick ash producers give the ash away. Farmers only pay for trucking.[184]

**Newfoundland**: In 2010 the government of Newfoundland announced $10k in support of a new research project at the College of the North Atlantic in Corner Brook to help determine whether the fly ash and bottom ash produced by the Corner Brook Pulp and Paper Mill can be safely reused for agricultural, horticultural and forestry applications. Funding was directed from Newfoundland's Multi-

[181] Per the document, it was anticipated that CAs would be replaced by project notices to make the process simpler and less costly. '*According to this approach, an agronomist must certify the compliance of the ash (with the BNQ standard), based on analyzes from the factories, cross-checked by a sampling firm accredited by the MDDEP. A certificate of compliance is then sent to the MDDEP in the form of a project notice*.'
[182] Hannam et al., 2016
[183] Government of New Brunswick, Department of Agriculture, Aquaculture, and Fisheries, 2021 - Funding to support soil productivity and sustainability project (News Release)
[184] Ford. R, 2019 – Ontariofarmer.com - Industrial Wood Ash is Popular in the Maritimes

Materials Stewardship Board through its solid waste innovation program.[185] No additional information or outcomes of the project were discovered in this literature review.

### *2.9.7 AshNet*

AshNet is a Canadian research and information-sharing hub. Its common interest is the potential beneficial diversion of wood ash sourced from the production of biomass energy, to forest soils.[186]

Funding for AshNet is provided by the Natural Resources Canada Program of Energy Research and Development (PERD) through the project entitled "Amelioration of biomass harvested sites with wood ash waste: improving Canadian forest productivity and sustainability through alternative approach to bioenergy waste management." Additional funding has been provided through the Canadian Wood Fibre Centre collaborative research project 3.3, "Sustainable supply of wood fibre for bio-economy opportunities." [187]

AshNet collaborators include members from federal and provincial government, academic, and industry researchers, foresters and policy makers. The Friends of the Muskoka Watershed (contract publishers of this document) are members of AshNet.

The spectrum of AshNet work includes the establishment of 14 experimental study sites across 5 provinces (BC, SK, MB, ON, QC).[188] These research sites span 10 different research groups.[189]

Emilson et al., (2018) explains: *"These field trials examine the implications of ash application across a variety of forest stand and soil types, tree species, stand ages, and ash chemistries and application rates. As a product of these research projects currently underway across Canada, a wealth of information on ash application protocols and methods exist."*[190]

As noted by Hannam et al., (2017): "*The results of these experiments will be used to assist policy makers and forest managers in developing best management practices specific to applications of wood ash on Canadian forest soils.*"[191]

We note that unlike the Friends of the Muskoka Watershed, AshNet's formal objectives are not driven by 'corrective' motivations (as in, correcting soils damaged from acid rain). Additionally, paradigms pertaining to 'watershed' health appear to be peripheral to AshNet study focus for the time being.

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[185] Government of Newfoundland and Labrador, Environment and Conservation, 2010 - Funding Announced for Research to Reuse Ash at Corner Brook Pulp and Paper

[186] Emilson. C, Hannam. K, Aubin. I, Basiliko. N, Bélanger. N, Brais. S, Diochon. A, Fleming. R, Jones. T, Kabzems. R, Laganière. J, Markham. J, Morris. D, Rutherford. M, Rees. K, Venier. L, Webster. K, Hazlett. P, 2018

[187] Emilson et al., 2018

[188] Emilson et al., 2018

[189] Emilson et al., 2018

[190] Emilson et al., 2018. **For more detailed information** on these research trials see Emilson et al., 2018 Synthesis of Current AshNet Study Designs and Methods with Recommendations towards a Standardized Protocol

[191] Hannam et al., 2017

AshNet has produced a dedicated website to house scientific, technological, regulatory and economic information about wood ash application on forest soils in Canada.[192] The AshNet website can be referenced here:

https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/great-lakes-forestry-centre/ashnet/20279

### *2.9.8 FPInnovations*

FPInnovations is a private, not-for-profit organization that specializes in the creation of solutions in support of the Canadian forest sector's global competitiveness.[193]

The organization is *"ideally positioned to perform state-of-the-art research, develop advanced technologies, and deliver innovative solutions to complex problems for every area of the sector's value chain, from forest operations to consumer and industrial products."*[194]

According to CCFM's Forest Sector Innovation in Canada 2015 report, FPInnovations was created from a merger of three leading Canadian research institutions that included: Paprican (Pulp and Paper Research Institute of Canada), FERIC (Forest Engineering Research Institute of Canada), and Forintek (Canada's wood products research institute). "*It is now the largest public-private forest research organization in the world*" and its membership represents approximately 50% of the forest sector's contribution to Canada's GDP. [195]

FPInnovations receives funding from Natural Resources Canada, provincial governments and its industry members.[196]

While much of the work done by FPInnovations is proprietary in nature and requires a paid membership, in relation to the use of wood ash as a forest soil amendment in Canada it is notable that FPInnovations has produced two significant and publicly accessible documents:

- Spreading Wood Ash on Forest Land in Canada: An Introduction (Nishio. G, Ersson. T, 2016)
- Ash and Biosolids Spreading Trial (Nishio. G, Ersson. T, 2016)

### *2.9.9 NCASI*

NCASI is an acronym for National Council for Air and Stream Improvement, Inc.. It is an association organized to serve the forest products industry as a center of excellence providing unbiased, scientific research and technical information necessary to achieve the industry's environmental and sustainability

[192] Hannam et al., 2017
[193] FPInnovations, 2023 – Who we are
[194] FPInnovations, 2023 – Who we are
[195] Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation In Canada (2015):White Paper: Opportunities for the Canadian Council of Forest Ministers
[196] Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation In Canada (2015):White Paper: Opportunities for the Canadian Council of Forest Ministers

goals. Their mission is to help its members cost-effectively meet their environmental and sustainability goals through basic and applied research, technical support, and education.[197]

Authors affiliated with NCASI (Lama, Sain, Vance) have published research or papers with industrial wood ash (particularly in relation to pulp and paper mills) as primary subject matter. Additionally, NCASI has published a 'Fact Sheet' on their website entitled '*Wood Ash As A Soil Amendment*.' However, similar to FPInnovations, access to proprietary information requires a paid corporate membership. Among other relevant pieces, it appears that NCASI has produced a '*Practical Guide for the Beneficial Use of Forest Products Residuals – Wood Ash*,'[198] however it is not publicly available and has therefore not been included in this literature review.

## 2.10 The International Picture

In a document published in 2006, Pitman noted that research into the composition and use of wood ash came from four main source countries: USA, Finland, Sweden and Denmark.[199] Since 2006, related research continues to be done in Europe, however a significant amount of material sourced for this document originated in Canada from the most recent decade (see *2.9.7 The State of Wood Ash Use in Canada/AshNet* as well as 2.9.8 *FPInnovations*, and 2.9.9 *NCASI*). However, beyond academic research, information pertaining to the practical, logistical, and experiential use of wood ash as a forest soil amendment continues to predominantly originate from Sweden and Finland. Nishio and Ersson (2016) state: "*Ash-spreading technology and infrastructure are more developed in the Nordic countries than in North America."*[200]

In its 2018 overview report on ash management practices (Options for increased use of ash from biomass combustion and co-firing), IEA Bioenergy collected information from the following countries: Austria, Canada, Denmark, Germany, Italy, the Netherlands, South Africa (limited), Sweden, and the United Kingdom (limited). While country reports were provided by five of these nations, clear, fulsome and equally comparative data was limited. Nevertheless, according to that report: *"Wood ash amendments are strongly recommended on forested stands from which residues have been removed for biomass production in Denmark, Finland, Lithuania, Sweden, and the United Kingdom."*[201]

As noted in IEA Bioenergy's earlier (2012) version of a similar report with the same name, guidelines for the practical use of biomass ashes on agricultural and forest soils are available in some countries. While they are not always legally binding, requirements typically: "*consist of limiting values for concentrations of certain heavy metal or organic compounds in the ash; limiting values for the maximum amount of ash applied per year and ha, based on the quality of the ash as well as on the type of soil (agriculture,*

[197] NCASI, 2023 – About NCASI
[198] https://www.ncasi.org/events/practical-guide-for-the-beneficial-use-of-forest-products-residuals-wood-ash/
[199] Pitman. R.M, 2006
[200] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[201] Hannam et al., 2016 (referencing Emilsson 2006; Karltun et al. 2008; Skogsstyrelsen 2008; Stupak et al. 2008; Forestry Commission 2009a, 2009b)

*grassland, forest); recommendations for the proper application of biomass ashes on agricultural (farmland and grassland) and forest soils."*[202]

In those countries actively recycling wood ash and using it as a forest soil amendment, motivation for doing so differs. In Finland, the use of wood ash is mainly performed to increase wood production whereas compensation of base cations and nutrients is most often the purpose in Sweden, Lithuania and Denmark.[203]

### *2.10.1 Denmark*

In Denmark's country report included in IEA Bioenergy's Options for increased use of ash from biomass combustion and co-firing 2018 document, it states "*In Denmark there is a legal order that describes how BMA [biomass ash] might be used… There is a strong incentive to use the BMA since there is also a tax regulation in place with the consequence of paying about 64 € (475 DKK ) per ton being landfilled (or deposited) rather than utilized. There is almost always a price tag on the utilization route but as a general rule lower than the tax… As a natural consequence landfilling or deposition is very limited and the use of the BMA order play an important role*."[204]

"*Use of BMA in forests is still a rather limited utilization partly because of tradition partly because of cost. Only few forest areas in Denmark are used for targeted production of wood. Therefore the outtake is not as extensive as in dedicated production forests. Denmark is mainly an agricultural country. Both uses are however covered in the BMA order*."[205]

### *2.10.2 Germany*

The degree to which wood ash is used as a soil amendment in Germany is unclear; however, from information discerned from a handful of reports, it is clear that activity is occurring and that some structure around its use has developed in that country.

The country report from Germany provided in IEA Bioenergy's Options for increased use of ash from biomass combustion and co-firing 2018, document mentions the use of biomass ash for forest liming. Only ash from untreated wood can be used and must meet other regulated requirements.[206]

As noted by Bachmaier et at (2021,) in the Federal state of Bavaria (i.e., Southeast Germany), "*a total of 30,000 to 60,000 t/a of wood ashes from untreated wood accumulates each year from plants with an installed capacity of more than 1MW (therm)*."[207] Bachmaier et al also notes "*many [*wood ash*] utilization pathways are still under development or in the pilot stage and are not applied regularly*."[208]

Two quality control systems for wood ash are in place in Germany. Quality control of wood ash, and a dolomite-wood ash mixture specifically designed for use in forests, is performed by the forest

[202] van Eijk. R.J Obernberger. I, Supancic. K, 2012
[203] Stupak et al., 2008, (referencing Emilsson, 2006; Koistinen & Äijälä, 2005)
[204] Lamers et al., 2018 (Chapter 6 Denmark: Bech. N, Primdal Dam. B)
[205] Lamers et al., 2018 (Chapter 6 Denmark: Bech. N, Primdal Dam. B)
[206] Lamers et al., 2018 (Chapter 7 Germany: Feuerborn, H)
[207] Bachmaier. H, Kuptz. D, Hartmann. H, 2021 (referencing 2018 Energy Wood Market Report of the Bavarian State Institue of Forestry (LWF)
[208] Bachmaier. H, Kuptz. D, Hartmann. H, 2021

administration of Baden-Wuettemberg [a state in the south-west of Germany] in co-operation with limestone plants.[209] Additionally, the Federal Quality Association for Wood Ash (Bundesgütegemeinschaft Holzasche e.V., BGH)) has developed a detailed catalogue of requirements and test algorithms that are used to certify wood ash as a fertiliser. Producers of wood ash who meet the BGH criteria are awarded the RAL-Dünger quality label.[210]

### *2.10.3 Finland*

While the practice of using wood ash as a forest soil amendment appears to be oldest in Finland[211], related material regarding the Finnish situation was not easily locatable (in English). Indeed, most information pertaining to Finland obtained for this report was provided or referenced in conjunction with Sweden. As such, information specific to Finland is scant.

In 2004, 27,000 tonnes of ash were used for forest fertilization in Finland.[212]The dominant purpose of spreading wood ash on forest lands in Finland has been to increase tree productivity on peatlands.[213]

### *2.10.4 Sweden*

Forests are an important natural resource in Sweden since they cover approximately 60 percent of the country's land area and account for 12% of Swedish export income.[214] The Swedish forest industry is the world's second largest exporter of timber. [215]

As explained by the Swedish Forest Agency in Sustainable forest management in Sweden (2011), 51% of the Swedish forest area is owned by private, small-scale, forest-owners, often called 'family forestry.' The proportion of forest managed through 'family forestry' is highest in southern Sweden[216] at 78%.

Acidification of land and water has been one of the most serious environmental problems in northern Europe since the late 1960s.[217] It is an issue of particular concern in Sweden.

The Swedish Forest Agency has recommended ash recycling after extraction of forest harvest residues since 1998.[218] Recycling ash to forest land in Sweden has been regarded mainly as an environmental measure with the main purpose to compensate for the removal of nutrients and acid-buffering capacity and to counteract historical acidification.[219]

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[209] Lamers et al., 2018 (Chapter 7 Germany: Feuerborn, H)
[210] Lehmann. H (Dr), 2020 - How natural cycles can be closed with wood ash
[211] **According to** Pitman. R.M, 2006 (referencing Hakkila, 1989; Korpilahti *et al.*, 1999): "***In Finland, wood ash has been used as a soil ameliorant for second-rotation conifer stands on drained peats, on sites monitored since 1935.***"
[212] Emilsson. S, 2006
[213] Emilsson. S, 2006
[214] Swedish Forest Agency (Skogsstyrelsen), 2011 - Sustainable forest management in Sweden
[215] Pembina Institute for Ontario Power Generation, 2011 - Biomass Sustainability Analysis: Summary Report 2011
[216] Swedish Forest Agency (Skogsstyrelsen), 2011 - Sustainable forest management in Sweden
[217] Emilsson. S, 2006
[218] Emilsson. S, 2006
[219] Emilsson. S, 2006

Ash recycling recommendations differ between the north and south parts of Sweden. This is because the southern part of Sweden has been more significantly impacted by historic acid rain.

While addressing the health and acidification of forest soils in Sweden is a motivation for the country's wood ash recycling recommendations, the development and reliance upon biomass based energy in the country provides additional context:

> "*Sweden uses a particularly large proportion of bioenergy (33% in 2016) mainly for heating. Almost half of all heating is delivered through district heating (DH) systems. Forest fuels dominate the bioenergy used for heat, and the use of logging residues, consisting mostly of tops and branches, recovered after final felling, is increasing*."[220]

#### 2.10.4.1 The Swedish Ash Programme, and RecAsh

While ash recycling had been recommended by the national forest agency in Sweden since 1998, it was noted in the early 2000's that recycling was not carried out to the extent that had been hoped.

In 2002, a research programme[221] under the title of 'Environmentally correct use of combustion residues' was launched by the Swedish Thermal Engineering Research Institute (Värmeforsk). Its purpose was to develop the knowledge needed to attain better utilization of combustion residues in Sweden. The programme was extended through to 2011 and was also known as the Ash Programme.[222]

The Swedish Ash Programme was co-financed by utilities, industry and the state through the Swedish Energy Agency. It was fundamentally a technical research, development, and demonstration program dominated by environmental questions.[223]

An area of focus for the Swedish Ash programme included *'compensating soils for removing biomass and the mineral nutrients in the biomass.'*

As explained by Bjurström and Herbert (2009) in a report on the Swedish Ash Programme: "*in spite of a general positive attitude among all stakeholders, 'lack of knowledge', and 'lack of plain regulation' were the main non-technical barriers to recycling wood ash to forest soils identified by the Swedish Forest Agency*."

To mitigate for this gap, the Swedish Forest applied for project funding from EU-Life Programme,[224] and funding was approved by the EU Commission in September 2003. The resulting project '*Regular*

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[220] Pettersson. M, Björnsson.l, Börjesson. P, 2020 (referencing Swedish Energy Agency, 2018; Ericsson and Werner, 2016)

[221] **In fact,** according to Levin. R, Eriksson. H, 2010, a series of major government-funded research programs on sustainable forest-derived bioenergy were undertaken in Sweden beginning from the 1980s and onwards.

[222] Bjurström. H, and Herbert. R, 2009. **For more detailed information** about this program, see Bjurström. H, and Herbert. R, 2009. The Swedish Ash Programme 2002-2008: Biomass, wastes, peat - any solid fuel but coal, A synthesis of the Ash Programme in English. Note: this report was intended for international audiences.

[223] Bjurström. H, and Herbert. R, 2009

[224] **The LIFE Programme** is the EU's funding instrument for the environment and climate action. https://cinea.ec.europa.eu/programmes/life_en

*Recycling of Wood Ash to Prevent waste Production*,' or, ***RecAsh***, ran from late 2003 to December 2006.[225]

The aim of the RecAsh project, was to create favourable conditions for regular recycling of wood ash to forest land. In addition to developing, analyzing, and demonstrating two regular ash-recycling systems, project activities included producing handbooks, promotional materials, a website, publishing articles, and organizing seminars and demonstrations, as well as conducting an ash classification study to support national actions for recommendations.[226]

Among the work done by RecAsh was the creation of a robust handbook intended for international audiences.[227] Much of the logistical and practical information pertaining to the spreading of wood ash on forest soils in this document (see *Chapter 3 Operational and Logistical Realities of Wood Ash as a Soil Amendment*) was drawn from the Swedish handbook published through the RecAsh project.

The RecAsh project expired in October, 2007.

#### 2.10.4.2. Swedish Ash Recycling Realities

Approximately 15,000 tonnes of ash was recycled to forest land annually in Sweden (2006) out of a potential 300,000 tonnes. One third of the ash was derived from power and heating plants, another third from the pulp and paper industry, and the remaining third from the sawmill industry.[228] In more recent years, the amount of ash recycled to forest soils in Sweden has increased to 50,000 tonnes annually.[229]

That said, despite decades of research and government promotion, the amount of ash recycled to forest soils in Sweden remains uncertain but is estimated at 20% or less.[230]

Despite government recommendations promoting ash recycling on forest soils, and significant quantities of ash being generated in the country through biomass energy systems, the notion of a shortage of 'suitable-quality ash' for forest recycling persists in Sweden. The rationale for this is explained in detail in Recycling of ash from co-incineration of waste wood and forest fuels: An overlooked challenge in a circular bioenergy system' (Pettersson. M, Björnsson.l, Börjesson. P, 2020). In short, logging residues are often co-incinerated with contaminated waste wood in DH plants in Sweden, thus contaminating the ashes and making them unsuitable as a soil amendment.

### *2.10.5 United States*

As noted elsewhere in this document, wood ash land application programs in the United States are evident, particularly in the Northeastern region of the country (see *2.5 Ash Uses*). However, similar to

[225] Swedish Forest Agency (Skogsstyrelsen), 2006 - Regular Recycling of Wood Ash to Prevent Waste Production: RecAsh - A Life-environment demonstration project (Layman's Report)
[226] Swedish Forest Agency (Skogsstyrelsen), 2006 - Regular Recycling of Wood Ash to Prevent Waste Production: RecAsh - A Life-environment demonstration project (Layman's Report)
[227] International Handbook: From Extraction to Forest Fuels to Ash Recycling (Emilsson. S, 2006)
[228] Emilsson. S, 2006
[229] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction (referencing Johanesson. T, 2015)
[230] Pettersson. M, Björnsson.l, Börjesson. P, 2020 (referencing SCB, 2012)

Canada, regulations pertaining to the use of wood ash as a soil amendment appear to be handled on a state-by-state basis and information in general is not easily locatable.

In terms of ash volumes produced in the United States, the following statistic was reported by Vance in 2000: "*The U.S. pulp and paper industry generated…2.5 million dry Mg of boiler ash as by-products in 1995. An additional 1.2 million Mg of wood ash (1990 estimate) is generated annually from the wood products sector of the U.S. forest products industry*."[231]

Based on a document from 2006, up to 70,000 tons of wood ash was spread on farmland every year in Maine.[232]

Based on 2018 data, Lama and Sain estimate that 17.1% of boiler ash from pulp and paper mills in the United States is recycled for land application purposes, 19.3% is used for other beneficial purposes, and the remaining 63.7% is landfilled.[233]

In the state of New Hampshire, wood ash is listed as a 'certified waste-derived product' (subject to specific conditions). A waste-derived product is produced using materials or items recovered or diverted from the solid waste stream. When a certified waste-derived product is used in accordance with the terms of its certification it is no longer regulated as a solid waste. Certified waste-derived products are associated with intended uses.[234] Paper wood/paper mill sludge ash material from the International Paper company is a certified waste-derived product and is authorized to be used for agricultural land application.[235]

Wood ash is sold commercially in the state of New Hampshire with spreader rentals and spreading services (agricultural) also being available.[236]

As pointed out in Wood Pellet Heating, a guidebook published by the Biomass Energy Center, Boston Massachusetts Division of Energy Resources, 2007, "*Massachusetts requires a 'beneficial use determination' from the DEP Bureau of Waste Prevention-Business Compliance Division before approving any use of the ash from pellet boilers.*" The guidebook goes on to say, "*Massachusetts considers wood ash from commercial or institutional sources to be a solid waste, thus potentially subject to the state's hazardous waste rules*." The guidebook does however point out: "*In reality, the only type of wood pellets that may not meet Massachusetts standards are those made from construction and demolition (C&D) waste wood material*."[237]

[231] Vance. E. D, 2000 (referencing NCASI, 1999; and Someshwar, 1996)
[232] University of Maine, Cooperative Extension, 2006 - Using Wood Ash on Your Farm.
[233] Lama. I, Sain. D, 2021
[234] New Hampshire Department of Environmental Services, 2023 - Certified Waste-Derived Products
[235] New Hampshire Department of Environmental Services, 2023 - Certified Waste-Derived Product No. 15 International Paper Wood/Paper Mill Sludge Ash Material Specifications and Restrictions
[236] Heart & Soil Ag Products [commercial], 2022
[237] Massachusetts Division of Energy Resources, Biomass Energy Centre, 2007 - Wood Pellet Heating

# 3.0 CHAPTER 3 Operational and Logistical Realities of Wood Ash Use as a Soil Amendment

There are many operational and logistical considerations to the spreading of wood ash on forest lands. They range from practical issues related to supply chain, regulatory approvals, material preparations, and site requirements, to the actual process of spreading ash on forest sites. And, while there are similarities in process between agricultural settings and forestry settings, there are some equally significant differences between the two settings, not the least of which being the difference in terrain, the structure of the 'crop', as well as the 'longer life of the crop.'[238] Agricultural crops are often grown and harvested in a single year, whereas forests grow over longer periods that span decades. Furthermore, in forest settings, there is a significant difference between spreading wood ash on previously logged forests (clear-cut and/or partial cut), and spreading wood ash on mature forests not previously harvested.

Given that spreading wood ash on forest soil is not a common practice in Canada or in most parts of the world, literature pertaining to the actual practicalities of spreading wood ash on forest soils is limited.

Material in this document is largely drawn from two published sources:

- From Extraction of Forest Fuels to Ash Recycling: International Handbook (Emilsson. S) was published by the Swedish Forest Agency in 2006 and was funded through the EU-Life RecAsh program (see *2.10.4.1 The Swedish Ash Programme, and RecAsh*). This international handbook provides comprehensive information on the practicalities of spreading wood ash on forest soils drawn from Swedish and Finnish experiences.
- The second document Spreading Wood Ash on Forest Land in Canada: An Introduction, (Nishio. G, Ersson. T,) was published by FPInnovations in 2016 and includes practical learning derived from Domtar's Windsor Mill experience spreading ash on its own lands in Quebec. Note: Domtar Windsor operates the largest ash-spreading program in Canada.[239]

## 3.1 Regulatory Approvals

As noted in section *2.2. Wood Ash Chemistry*, the chemistry of wood ash is dependent upon what is burned, and how it is burned. Given its potential to contain harmful properties, the usage of wood ash as a soil amendment necessarily requires some regulation. While this reality is ubiquitous regardless of country or location, the nature and process of attaining regulatory approval differs by jurisdiction.

For more contextual information see *2.9.1 The State of Wood Ash Use in Canada/Regulatory Situation*. For a more fulsome description of regulatory realities on a province-by-province basis, see Hannam et al. (2016), Regulations and guidelines for the use of wood ash as a soil amendment in Canadian forests.

Attaining regulatory approval is not necessarily expeditious, and it is therefore prudent to anticipate process times anywhere from several months to a year. For example, as noted by Nishio and Ersson

[238] Pitman. R.M, 2006
[239] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction

(2016) in Spreading Wood Ash on Forest Land in Canada: An Introduction, Domtar Windsor Mill has experienced the approval process taking anywhere from three months to a year.

In many instances it is recommended that local authorities be consulted when seeking regulatory approval for using wood ash as a soil amendment.[240]

In Ontario, spreading wood ash on forest soils requires an Environmental Compliance Approval (ECA).[241] ECAs are handled by the Ministry of the Environment, Conservation and Parks (MECP) on a case-by-case basis; they are conditional, and they expire. Applications and guidelines on how to apply for an ECA are available on the MECP website.

While ECA application requirements are necessarily determined by the specific nature of the ECA request, based on the Friends of the Muskoka Watershed's experience recycling *non-industrial* wood ash (i.e. ash collected from local residents), the following may be required as part of the ECA application process:

- Confirmation that the ash will have value as a soil amendment at the intended dispersal site
- Details on where the wood ash will be collected, stored, and dispersed
- Details on how the wood ash will be transported
- GIS maps of the intended dispersal site location
- Specific chemical analyses of dispersal site soil
- Details pertaining to wood ash dosage, and dispersal site conditions including soil depth
- Chemical analysis of the wood ash being used including:
    - Chemical analysis of trace metals
    - Analysis of various nutrient quantities (nitrogen, phosphorus)
    - Acidity and organic content
- Biosolids Utilization Committee (BUC) recommendation re classification of *Wood Ash as a 'Non-Agricultural Source Material' (NASM)*

The closest regulatory classification that fits the profile of industrial wood ash, and the intended purpose of using it as a forest soil amendment, is 'non-agricultural source material' (NASM). According to the Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA):

> *"Non-Agricultural Source Material, or NASM, is treated and recycled material from non-agricultural sources, like leaf and yard waste, fruit and vegetable peels, food processing waste, pulp and paper biosolids and sewage biosolids, that is applied to agricultural land to provide a beneficial use."*[242]

While NASM is the 'closest' regulatory classification for wood ash, it is notable that wood ash does not actually closely resemble NASM chemically. For example, high levels of ammonia or nitrogen are a

[240] Friends of the Muskoka Watershed, 2021 - Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide, by permission.

[241] **Detailed information pertaining** to Environmental Compliance Approvals can be referenced from the Ontario Environmental Protection Act, regulations 255/11 and 347, and from the Ontario Nutrient Management Act, regulation 267/03.

[242] Government of Ontario, Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2023 - Non-Agricultural Source Materials

concern with traditional NASM, whereas these elements are largely consumed when wood is combusted.

The classification and safe usage of NASM in Ontario is evaluated by the Biosolids Utilization Committee (BUC). The BUC is a multi-stakeholder, inter-ministerial committee that advises and makes recommendations to the MECP and OMAFRA on matters related to the use of biosolids and other materials (NASM) on agricultural land.[243]

## 3.2 Dispersal Site Characteristics

As noted in the previous section, for regulatory and environmental safety reasons, wood ash as well as the soil at dispersal sites must be chemically tested to determine appropriateness of use. This is typically part of the regulatory approval process as noted by Nishio and Ersson (2016): "*The chemistry of the soils at the application site and of the ash must be tested to ensure the soil nutrient requirements and pH at the site corresponds to the characteristics of the ash, and to verify the application rationale.*"[244]

Commercial labs exist where such tests can be performed. In some provinces such as Quebec, it is advised, or required, to engage a qualified professional to facilitate or certify aspects of dispersal site characteristics.

Incidentally, in the Nordic countries and the United Kingdom, ash recycling recommendations first classify sites and stands according to the sensitivity of the forest to fuel extraction. Different restrictions are then imposed for the specific site types.[245] Site and stand classifications consider ecosystem types, soil type, forest type, soil fertility, wood production, soil compaction, and slope. In some cases tree species and atmospheric deposition [acid rain] is used to distinguish sites.[246]

### *3.2.1 Dispersal Site Limitations*

Restrictions on where to spread clean ash typically involve proximity to wetlands, water or watercourses; proximity to other shared/public spaces such as roads and recreation areas; and proximity to private dwellings. In some instances recommendations include avoidance of certain types of vegetation (e.g. lichen and mosses),[247] as well as areas of specific conservational concern.[248]

In Ontario, when considering an ECA submission, an MECP inspector will likely want to visit the ash dispersal site to confirm the details of the ECA submission.

From a regulatory perspective, the following attributes of the dispersal site location are noteworthy and may be included (among other things) in the 'terms and conditions' of an ECA.[249]

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[243] Government of Ontario, Ministry of Agriculture, Food and Rural Affairs (OMAFRA), 2023 - Nonagricultural Operations
[244] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[245] Stupak et al., 2008 (referencing Billeschou & Klitgaard 1985; British Biogen 1999; Danish Forest Agency 1985; Koistinen & Äijälä 2005; National Board of Forestry 2002; Nisbet et al. 1997)
[246] Stupak et al., 2008
[247] Emilsson. S, 2006
[248] de Jong. J et al., 2014; Emilsson. S, 2006
[249] Friends of the Muskoka Watershed, 2021 - Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide, by permission.

- Is the location of the site a minimum of:
  - 250 meters away from 'sensitive use'[250] areas, and/or residential areas
  - 100 meters away from a municipal well
  - 90 meters away from a private well
  - 90 meters away from a single residence
  - 60 meters away from surface water (e.g., lakes, rivers, ponds, streams, wetlands, swamps, etc.)
  - 30 meters away from a public roadway
- Do any areas of the site have a maximum sustained slope greater than 50%
- Is there exposed bedrock
- Is the depth of soil sufficient to impede immediate runoff of ash into watersheds

Comparatively, the following distance requirements are noted in the handbook from Sweden:[251]

- 50 meters from sources of water supply, rivers and lakes, buildings, farmyards and gardens
- 20 meters from tarns [small mountain lake], ponds and streams
- 10 meters from public roads and other people's land

It is notable that the restrictions regarding proximity to water in Ontario are precautionary based on an underlying assumption that wood ash is potentially hazardous. In Sweden, restrictions regarding proximity to water are imposed for reasons of nature conservation, presumably to preserve ground habitats in those areas.[252]

## 3.3 Dosage and Frequency

In terms of volume per hectare and frequency of application, ash dosage recommendations or requirements vary depending: on ash composition, characteristics of the receiving soil, dominant type of tree species (or crop), existing flora and fauna, purpose of use, and whether biomass harvesting will occur.[253] Respecting environmental concerns, liming requirements and heavy metal concentrations are typically (although not exclusively) the primary limiting factors in ash dosage recommendations.[254]

Since the above variables can differ substantially by location, dosage recommendations in the literature reviewed for this document differed considerably.[255]

As pointed out by Kim et al., (2022): "*In Canada, maximum wood ash dosage rates have not yet been established for forest soils, but they do exist for agricultural soils and are much higher than the European guidelines for forest soils.*"[256]

[250] **This includes** commercial, recreational, or institutional uses, and locations where people regularly congregate (i.e., parks, sports fields, recreational areas).
[251] Emilsson. S, 2006
[252] Emilsson. S, 2006; Stupak et al., 2008
[253] Kim. N, Watmough. S, Yan. N, 2022
[254] Hannam et al., 2016
[255] Hannam et al., 2016; Pitman. R.M, 2006
[256] Kim. N, Watmough. S, Yan. N, 2022 (referencing Hannam et al., 2018)

Wood ash study trials across the AshNet research network use doses ranging between 0.5–20.0 Mg·ha−1. It is anticipated that their findings will provide additional insight for optimal ash dosing in Canada.[257]

In forested areas of central Ontario that are affected by Ca [calcium] decline, the estimated dose of wood ash needed to alleviate Ca deficiency in forest soils is roughly 2 tons·ha−1. This dosage is exclusive of biomass harvesting activity. In the absence of biomass harvesting, a single 2 ton/ha−1 dose of ash may be sufficient for restoring Ca to pre-acidification concentrations,[258] assuming most of the Ca in the ash is available to forest plants. The rationale for this dosage is based on the determination that 0.5 tons·ha−1 of calcium has been lost from forest soils in Central Ontario. Given that wood ash is comprised of approximately 25-30% calcium, and the availability of that Ca is high (i.e., 90%), the dose needed to replace the lost exchangeable Ca is about 2 tons·ha−1 of ash.[259]

For a more fulsome review of dose and application frequency information see Kim, Watmough, and Yan, (2022); and Hannam et al., (2018)

**Sweden**

The maximum dose allowed in Sweden is 3 tonnes of wood ash (dry weight) per hectare. Lower doses are recommended for less fertile soils.[260] The governing principle is balance between removal and restitution of both nutrients and trace elements.[261] As pointed out by Kim et al., (2022): "…*guidelines state that precautions are needed to ensure that nitrogen leaching and loss of added nutrients are minimal and that the total amount of contaminants (e.g., heavy metals) being added via the ash fall below the amount lost through biomass removal over the span of the rotation period."*[262]

**Finland**

While 3 tonnes of wood ash per hectare is the maximum dose permitted in Sweden, Finland permits the usage of higher doses when increased tree growth on drained peatland is the objective.[263] The dose rate of wood ash in Finland is generally 3 - 5 tonnes per hectare.[264]

**Denmark**

[257] Hannam et al., 2018
[258] Kim. N, Watmough. S, Yan. N, 2022 (referencing Watmough and Dillon 2004; Ott and Watmough 2022; Azan et al. 2019)
[259] Kim. N, Watmough. S, Yan. N, 2022 (referencing Watmough and Dillon 2004; Ott and Watmough 2022; Azan et al. 2019)
[260] Swedish Forest Agency (Skogsstyrelsen), 2007 - Regular Recycling of Wood Ash to Prevent Waste Production (RecAsh). Technical Final Report
[261] Bjurström. H, and Herbert. R, 2009
[262] Kim. N, Watmough. S, Yan. N, 2022 (referencing Emilsson, 2006; Bang-Andreason et al. 2021.)
[263] Swedish Forest Agency (Skogsstyrelsen), 2007 - Regular Recycling of Wood Ash to Prevent Waste Production (RecAsh). Technical Final Report
[264] Emilsson. S, 2006

Although use of wood ash as a forest soil amendment is rather limited in Denmark (since it is mainly an agricultural country),[265] up to 3 tons· ha−1 of wood ash may be applied every 10 years for each 70-year growth cycle.[266]

## 3.4 Co-applications

Wood ash has very little nitrogen which is a key requirement of plant growth; therefore, in soils depleted of, or in requirement of nitrogen, nitrogen should be added to wood ash when it is intended for use as a fertilizer. This would often be the case in agricultural settings as well as in forest settings where forest residues have been harvested on non-acidic soils. However, soils receiving high acid deposition typically suffer from an overabundance of nitrogen; therefore, adding nitrogen to wood ash is not necessary when fertilizing these locations, nor are the low concentrations of N in the ash problematic for its use as a fertilizer.

It is generally recommended in the Nordic countries that fertilization (or compensation) with nitrogen take place in areas with an atmospheric deposition less than 15 kg ha–1 yr–1. [267] Simultaneous applications of lime (limestone or dolomite) and ash are recommended in severely acidified watersheds.[268] Emilsson (2006) explains further: *"The main method for remediation of acidified land in Sweden is based on applying a mixture of two tonnes of ash and two tonnes of lime. The lime should consist of carbonate limestone and/or dolomite and have a granule size distribution that allows slow dissolution. The treatment should probably be carried out per catchment and may also be applied independently of forest fuel extraction. Lime should not be added in catchments where the run-off water is acidic as a result of natural causes."*[269]

## 3.5 Timing

Provincial, territorial, or regional regulations or guidelines pertaining to the timing of ash dispersal may apply and may include conditions such as:

- Ash should not be dispersed over top of snow because snow migrates and can take the ash with it. For similar reasons, ash should not be dispersed on frozen ground, or ice.
- Ash should not be dispersed during periods of heavy rainfall, or on windy days.
- Ash should not be dispersed on ponded water, on flooded or saturated areas, or on exposed bedrock.[270]

Based on their experience spreading ash on forests soils in Muskoka for study purposes, the Friends of the Muskoka Watershed find that the optimal time to spread ash is late August to early November. This time frame optimally avoids snow, frozen ground, ground thaw, and minimizes risk to delicate forest floor vegetation. It also, conveniently, avoids 'black fly' season which could otherwise cause discomfort

[265] Lamers. F. et al., 2018 (Chapter 6 Denmark: Bech. N, Primdal Dam.B)
[266] Kim. N, Watmough. S, Yan. N, 2022 (referencing Emilsson, 2006; Bang-Andreason et al. 2021.)
[267] Stupak. I, Asikainen. A, Röser. D, Pasanen. K, 2008
[268] Hannam et al., 2016 (referencing Emilsson, 2006)
[269] Emilsson. S, 2006
[270] Friends of the Muskoka Watershed, 2021 - Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide (by permission)

for people working in that environment. Another benefit of this time frame is that it allows the ash to 'stabilize' prior to plant uptake in the Spring.[271]

### *3.5.1 About: Forest Phase*

While this document primarily speaks to the purpose of using wood ash as a soil amendment to remediate calcium decline due to acid deposition, using wood ash as a soil amendment to compensate for the removal of nutrients from the harvest of forest biomass residues is of prominent interest to governments and industry. As such, the appropriate timing of wood ash application is also dependent upon the forest phase (relative to harvest).

In that context, the general recommendation is that application of ash not be performed later than 5 years prior to harvest, or earlier than 5 years after harvest.[272] The rationale for this is that ash application on bare soil increases the risk of nitrification and leaching of potassium and nitrate from the harvested area.[273]

## 3.6 Ash Processing (also referred to as Pre-treatment, Stabilisation, Hardening, or Aging)

While The Friends of the Muskoka Watershed have experience spreading unprocessed ash on forest soils, this has been done on a small scale by hand using only buckets and shovels. To spread ash on forest soils at scale, the feasibility of doing so is greatly enhanced by hardening and agglomerating the ash prior to dispersal (also referred to as pre-treatment or stabilisation).[274] This serves multiple purposes:

- It reduces wear and tear on spreading machinery and makes it easier to spread the ash more evenly.[275]
- It reduces potential health and safety risks to workers from the fine particulates and corrosiveness of raw ash – the particular concern being aspiration of the material by workers.
- It slows the nutrient release rate in the ash and prolongs its fertilizer affect, particularly if it is granulated or pelletized.[276]

Three forms of ash agglomeration are noted in literature from Sweden: Self-hardening and screening, granulation, and compaction (pelletizing).

As noted by Nishio and Ersson (2016): "*A few commercial ash-spreading companies are currently operating in Sweden, but the industry is less developed compared to that in Finland. Sweden's largest ash-spreading company, Askungen Vital AB…" "Because of the ecological and operative advantages of processed ash, Askungen Vital spreads only self-hardened ash. Self-hardening followed by crushing and*

[271] Yan. N, Friends of the Muskoka Watershed, 2023 (personal communication)
[272] Emilsson. S, 2006
[273] Emilsson. S, 2006
[274] de Jong. J et al., 2014; Knapp. B, and Insam. H, 2011 (referencing Sarenbo et al. 2009)
[275] Pitman. R.M, 2006 (referencing Hakkila, 1989; Wilhoit and Qingyue, 1996); Stupak. I. et al, 2008
[276] Knapp. B, and Insam. H, 2011 (referencing Sarenbo et al. 2009); Emilsson. S, 2006; Kim. N, Watmough. S, Yan. N, 2022 (referencing Pitman, 2006)

*screening is the most cost-efficient processing method in Sweden, and Askungen Vital operates its own terminals where ash can be cured if a mill or plant prefers that the ash is processed off site.*"[277]

Regardless of pre-treatment method, BNQ certification standards in Quebec (2008 context), require that 98% of ash particulates be able to pass through a 20 mm sieve, while 95% must be able to pass through a 12.5 mm sieve.[278]

All forms of ash pre-treatment begin with wetting the ash with water. Adding water to ash chemically alters it by converting the calcium oxides in the ash to calcium hydroxide, also known as slaked lime. Subsequent exposure to the air for a few weeks to months converts the calcium oxide to calcium carbonate, thereby hardening it. This process reduces the pH and corrosiveness of the ash, as well as binds the ash with CO2 from the atmosphere (thereby contributing to the mitigation of climate change.) The hardened calcium carbonate takes the form of a hard plaque which must then be crushed, or granulated.[279]

### *3.6.1 Wetting*

Details pertaining to the types of machinery that can be used to wet the ash can be found in Emilsson. S, 2006. One example provided is a rotating cement mixer.

According to Emilsson (2006) the amount of water to be added to the ash is dependent upon the type of agglomeration or pre-treatment method being employed; water and ash must be mixed very carefully and in the right ratios (approximately 40% for fly ash and 15% for bottom ash, computed as water ratio)."[280]

The Ministry of the Environment (British Columbia) in Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice provides this direction: "*Excess water can result in the ash caking and becoming difficult to spread evenly. Optimum wetting of ash for dust control appears to be in the range of 25-35% moisture. Lumps may form following wetting of ash; these should be screened out prior to loading ash into the application equipment to avoid internal damage to equipment during spreading*."[281]

### *3.6.2 Self-hardening, Crushed, and Screening*

The self-hardening technique involves spreading wetted ash on a paved surface, and allowing it to self-harden over a period of time. The time it takes for the ash to harden is dependent on several factors including temperature and ash quantity, but with good handling it should only take a few months.[282]

Once hardened the ash is broken up and crushed using excavators and/or crusher or sieving bucket (a tractor-mounted bucket with rotating crushing cylinders fitted in the base). Once ash is crushed down to

[277] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[278] Hébert. M, Breton. B, 2008 (referencing BNQ 0419-090)
[279] Yan. N, Friends of the Muskoka Watershed, 2023 (personal communication)
[280] Emilsson. S, 2006
[281] British Columbia, Ministry of Environment (Sylvis Environmental), 2008 - Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice
[282] Emilsson. S, 2006

a spreadable/manageable size[283] it can be loaded directly into a dump truck for transport, or stored (see *3.7 Storage*).[284]

Self-hardening is the least expensive form of ash pre-treatment. According to the Swedish Forest Agency (2007) it is the most widely practised technique in that country, "*mainly because it is cheap and requires little ancillary equipment. The cost is between €10 and €20 per ton of ash* [2007 context]." [285]

For further details on this form of ash processing see Emilsson. S, 2006.

### *3.6.3 Granulation*

Granulation of ash involves rolling the wetted ash mixture in a drum or on a plate until granules are formed. The granules are then dried in hot air – or allowed to self-dry - so that they don't stick together.[286]

Various types of binding agents or nutrient mixtures can be added to the ash mixture if necessary during this form of ash processing;[287] however, for addition to Ontario forests, additional nutrients should not normally be necessary. The ash has the necessary base cations in the proportions needed by the trees, and the missing nitrogen should not normally be an issue in forested areas affected by decades of acid rain.

Similar to self-hardened/crushed ash, ash granules can be spread on agricultural or forest soils using the same equipment as that used for other agricultural or forest soil fertilizers; however, ash granules allow for more cleaner handling, and are more uniform in size than crushed ash and thus can be spread more precisely and in a more controlled manner.[288]

A commercial provider of ash granule technology is a company called Tecwill Granulators Oy. The diameter of the ash granules they produce is 3-10 mm.[289]

As noted by Nishio and Ersson (2016), granules are the preferred ash product used in Finland. At bigger mills/cogeneration plants in that country, granulation of ash is often done on site using commercially available granulation stations.[290]

### *3.6.4 Compaction/Pellets*

The compaction process of agglomerating ash involves pressing wetted ash into cylinders, or pellets. Ash pellet techniques have been developed in Sweden, and have included the testing of pellets made with

[283] **Crushed and sieved to a** achieve particle size under 5mm (Pitman. R.M, 2006)
[284] Emilsson. S, 2006
[285] Swedish Forest Agency (Skogsstyrelsen), 2007 - Regular Recycling of Wood Ash to Prevent Waste Production (RecAsh). Technical Final Report
[286] Emilsson. S, 2006
[287] Emilsson. S, 2006
[288] Emilsson. S, 2006
[289] Tecwill Granulators Oy, 2022 - Bio Fly Ash Is Too Valuable to Waste (commercial brochure)
[290] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction (referencing Huotari, 2012: and Rompannen, 2016)

mixtures of ash-green liquor sludge and ash-lime sludge from pulp and paper mills. The ash pelletization equipment developed in Sweden is mobile, and easy to transport and install.[291]

Similar to the granulation process, binding agents or nutrient mixture can be added to the ash if required.[292]

Once produced, pellets require one month to harden.[293] They can then be handled without risk of breaking down to any appreciable extent.

The compaction process increases the contact between the water and the ash and creates nearly optimal conditions for chemical hardening of the mixture.

Given the preference for self-hardening or granulation treatments, it is not clear from the literature whether the ash compaction/ash pellet pre-treatment option is widely practised.

## 3.7 Storage

Based on Friends of the Muskoka Watershed experience, loose, untreated ash has an average dry weight of approximately 550 kg per m3 and 1 tonne of ash will occupy approximately 1.82 m3 (2.38 cubic yards). [294]

According to Tecwill Granulators Oy, one litre of granulated ash weighs about 1 kg. [295]

Processed ash is sensitive to rewetting and dehydration and should be covered to protect it from heavy rain and/or if it is going to be stored for a long period before application.[296]

Tecwill Granulators Oy state that their granulated ash can be stored for short periods of time outside in piles.[297]

Storage of ash may be (and often is) governed by provincial, territorial, or regional regulations or guidelines concerned with proximity to waterbodies and wetlands, wildlife, groundwater, and community spaces.[298] Storage of ash must generally ensure protection against leakage, and if untreated ash is not stored in sealed containers or locations, keeping it dry and protected from excessive air currents is of paramount importance.

Based on FOTMW's experience recycling residential wood ash in Ontario, ash storage regulatory requirements include:[299]

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[291] Emilsson. S, 2006
[292] Emilsson. S, 2006
[293] Emilsson. S, 2006
[294] Friends of the Muskoka Watershed, 2021 - Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide (by permission)
[295] Tecwill Granulators Oy, 2022 - Bio Fly Ash Is Too Valuable to Waste (commercial brochure)
[296] Emilsson. S, 2006
[297] Tecwill Granulators Oy, 2022 - Bio Fly Ash Is Too Valuable to Waste (commercial brochure)
[298] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[299] Friends of the Muskoka Watershed, 2021 - Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide (by permission)

- A minimum distance of 60 meters away from surface water (e.g., streams, rivers, watercourses, wetlands, lakes, etc.)
- A minimum distance of 250 meters away from 'sensitive use' areas, and/or residential areas
- A minimum distance of 90 meters away from a single residence
- A minimum of distance of 30 meters away from a public roadway

Within the context of pulp and paper mill land application [agricultural] practises in North America, Lama and Sain note that: "*in most cases ash is stored outside and uncovered at the forest products facility. Some facilities spray water on the ash to control dust, but typically ash is stored dry. It can be stored for long periods (from weeks to several months), especially if covered and/or humidified… Some facilities in the United States have reported use of indoor storage structures*."[300]

## 3.8 Site Staging

Ash necessarily needs to be transported to a staging site from its source location. The staging site is where the ash is made accessible to the machinery engaged in spreading it over the dispersal area.

The distance between the roadside staging site and the treatment area has significant implication on costs. In the case of ground spreading (see *3.10 Methods of Spreading*), this is because tractor spreaders have a low top-speed even when running empty. Distances from staging areas greater than 1 km make application considerably more expensive.[301]

As described and illustrated in Nishio and Ersson's Spreading Wood Ash on Forest Land in Canada: An Introduction, (2016) once Domtar Windsor Mill identifies potential ash spreading areas (ruling out proximity to watercourses, terrain challenges, etc.), and has received site specific government approvals, the prospective areas are field inspected for blow-down, and vehicle access. Optimal staging site or potential ash depot locations are then determined. Staging sites respect distance requirements from waterbodies, and are spaced approximately 500 meters apart. Ash depots are located adjacent to existing forest roads or trails, and pads or small road spurs are then built with an excavator to receive the dumped ash at these sites. Ash is transported to the pad by dump trailer. Spreading machines use their forwarder cranes to load the ash into their hopper/spreader units and then traverse to the designated treatment area for dispersal.[302]

In Finland, when ash is spread by ground, granulated ash is simply unloaded on the ground at roadside or delivered in big fertilizer bags. Due to its nature and texture, there are generally no aesthetic or road quality issues if remnants of granulated ash are left behind at roadside staging sites.[303]

In Sweden, Askungen Vital delivers self-hardened ash to its roadside operations in detachable dump bodies.[304] From a logistical perspective these 'lift dumper systems' seem to make the most sense since

[300] Lama. I, Sain. D, 2021
[301] Emilsson. S, 2006
[302] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[303] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[304] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction

they require relatively light vehicles which allow for higher utility loads. Additionally, containers are easily parked in the forest.[305]

## 3.9 Transportation

Ash needs to be transported from the location it is generated – which may or may not also be the location where it is processed or stabilized – to the forest spreading site. Untreated ash should be contained or covered while in transit to mitigate release of fugitive dust.[306]

Specialized spreading equipment also needs to be transported to and from the forest spreading site.

Depending on location and distances, transportation costs represent a considerable proportion of total costs. Related cost considerations include licencing fees, loading and unloading the ash, round-trip transportation distances, number of trips, and road type.[307]

Within the context of agricultural land application programs in North America, Lama and Sain (2021) note that the ash generator or the broker typically cover the cost of transportation to the application site. As noted earlier is this document, the government of Nova Scotia subsidizes the cost of transporting ash to agricultural sites.

Resolute Forest Products in Thunder Bay, Ontario transport their ash to farmers within a 30 km radius for agricultural land application via dump trucks. Depending on truck size and road weight restrictions, they usually get between 10-14 MT of material into the truck.[308]

## 3.10 Methods of Spreading

As noted earlier in this document, spreading ash in forest settings involves significantly more challenges than spreading ash in agricultural settings. This is largely due to differences in access and type of terrain, as well as the presence of mature vegetation.

### *3.10.1 Agricultural Contexts*

For agricultural land application, ash can be spread by conventional manure spreading equipment.[309]

Hebert and Breton (2008) note: [English translation] "*Ashes that contain little moisture and clods can be spread with mineral fertilizer spreaders, while with wetter ashes lime spreaders are preferred. However, this equipment is not easily accessible and does not allow high doses. Standard manure spreaders can then be used; these also have the advantage of being more robust. However, the spreading pattern would be more random. New precision manure spreaders would be ideal in terms of spreading pattern, sturdiness and spreading rate*."[310]

[305] Emilsson. S, 2006
[306] Lama. I, Sain. D, 2021
[307] Hope. E. S, 2016
[308] Yan. N, Friends of the Muskoka Watershed, 2022 (personal communication)
[309] Campbell. A.G, 1990
[310] Hébert. M, Breton. B, 2008 (referencing Vigneux, 1991; Coleman, 1995)

### *3.10.2 Forest Contexts*

In Canada, there has been limited ash application in forests via mechanized means and applied at a scale greater than five hectares per plot.[311]

Per literature from Sweden, ash can be spread in forest settings by ground, or by air. In Sweden and Finland, while application by air has been tested and practiced, ground application is more common due to lower cost.[312] No instances of air application in North America were discovered in this literature review.

### *3.10.3 Ground Application*

Ground application of ash in forest settings is operationally more feasible when the forest has been previously harvested or industrially planted. This is because in these areas, skid roads and trails have already been established for machinery to pass through.

Ground application considerations include: terrain, ground conditions, slope, distance of treatment area from watercourses, existence of roads/trails for spreading machinery to operate within the treatment area, and distance from staging/loading areas.

As noted earlier, the use of wood ash as a soil amendment in forests is quite limited in North America; however, as noted by Nishio and Ersson (2016) it generally has involved modified agricultural spreader units mounted on forestry forwarders.[313] Details on land-spreading equipment, as well as some testing results (with associated cost analysis) are provided in two FPInnovations reports: Spreading Wood Ash on Forest Land in Canada: An Introduction',[314] and 'Ash and Biosolids Spreading Trial.' [315] [316]

Details on ground spreading ash in the Nordic forests is provided in Emilsson, (2006) 'From Extraction of Forest Fuels to Ash Recycling: International Handbook.' Information is based on ash that is spread on growing stands. Emilsson notes that that while forwarders can drive on skid roads with ash loads of up to six tonnes, smaller tractors (usually farm tractors), can be driven into the stand without using skid roads; however, these smaller tractors naturally have smaller load capacities of about 2-3 tonnes. The type and size of vehicle also impacts swath size which ranges from 25 meters for forwarders, and 18-20 meters for smaller tractors.[317]

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[311] Emilson et al., 2018

[312] Swedish Forest Agency (Skogsstyrelsen), 2007 - Regular Recycling of Wood Ash to Prevent Waste Production (RecAsh). Technical Final Report

[313] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction

[314] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction

[315] Nishio. G, Ersson. T, 2016 - Ash and Biosolids Spreading Trial

[316] **Additional Note:** While wood ash use as a fertilizer on forest soils has not been practiced in Latvia [2017], a detailed study on the 'Productivity of mechanized wood ash application in forest' has been published by an author from the Latvian State Forest Research Institute (Latvijas Valsts mežzinātnes institūts). The aim of the study was to analyze the productivity of ground based mechanized woody biomass ash spreading using four-wheel agricultural tractors, combined with either a modular ash spreader, or a regular fertilizer spreader. **For more details** see Okmanis. M, Petaja. G, Lupikis. A, 2017

[317] Emilsson. S, 2006

Dose size can be controlled by the belt speed and hatch size of the spreader equipment. Driving speed is usually maintained at 50 meter/minute.[318]

While spreading ash using forwarders and tractors is less feasible in mature forests, a Sugar bush operator in Ontario has explored spreading ash in a mature forest using an ATV pulling a modified manure spreader.[319]

### *3.10.4 Application by Air (Helicopter)*

In practical terms, ash spread over forest soils by helicopter involves loading ash into a spreading container that is suspended below the helicopter when it is airborne. GPS is used to determine and record the area where the ash is then released. Per Swedish literature, the loading capacity of the container is documented at about 500kg, and typical ash spreading capacity is 100 tonnes per day (in one shift).[320]

Spreading ash by helicopter is more logistically and economically feasible than ground spreading when forest treatment areas are dense and do not have existing roads or trails, or when slope and terrain are challenging. Spreading by air is also advantageous when bearing capacity of the soil is a concern.[321] However, the disadvantages of spreading ash by air is the application pattern is less accurately discernable, particularly when crushed ash (with more fine fractions) is used. The latter issue can be accommodated by using granulated ash.[322]

## 3.11 Record Keeping and Monitoring

Documenting wood ash applications is a common recommendation or requirement in the literature. In guidelines from Alberta [agricultural focus] and from Sweden, documentation is recommended in order to prevent over-application.[323]

In Finland it is obligatory to keep a historical record of wood ash applications. This is because many years can pass between forest fuel harvesting and wood ash compensation. Forest owners' associations keep records on the fertilized sites where the operation is contracted by the association. In instances where ash is applied to improve forest health and a state subsidy is received, the operation is documented by regional Forestry Centres.[324]

Guidelines for record keeping may require the following:

- Source of wood ash by generator and location
- Location of wood ash application sites
- Date of ash application
- Quantity of ash distributed at each site

[318] Emilsson. S, 2006
[319] Yan. N, Friends of the Muskoka Watershed, 2023 (personal communication)
[320] Emilsson. S, 2006
[321] Emilsson. S, 2006
[322] Emilsson. S, 2006
[323] Hannam et al., 2016 (referencing Alberta Environment 2002; Emilsson 2006; Stupak et al. 2008)
[324] Stupak et al., 2008

- Analytical results of ash and/or soil chemical testing
- Date and location of each wood ash delivery
- A copy of the site-specific management plan for each land application site where the wood ash is used

Additionally, if wood ash is being applied to compensate for nutrients removed during biomass harvesting in Sweden, the following is also required:[325]

- Tree species harvested
- Quantity of biomass removed
- Date of extraction
- Removal or retention of foliage

## 3.12 Occupational Health and Safety

In general, health and safety issues pertaining to the handling of wood ash as a forest soil amendment are not mentioned as a significant limitation to its utilization.[326] However, as with all matters of health and safety, it is critical to uphold mindfulness and integrity towards preventative measures.

Appropriate eye and respiratory protection (PPE) should be used when handling ash as dust particulates in fly ash can be hazardous to the respiratory system and mucous membranes.[327] Additionally, skin should be protected when handling wet ash as in a wet state ash becomes highly alkaline and can cause corrosive burns.[328]

Hot embers in uncooled ash or in ash that has not been treated with water is a fire hazard, thus, care should be taken to ensure ash is completely cooled prior to handling, storage, or transport.

## 3.13 Costs

Costs associated with wood ash application on forest soils include: ash and soil testing, regulatory approval fees, pre-treatment, storage (at supply location and site location), ash transportation, equipment transportation, equipment operation (i.e., fuel), transportation distances, monitoring and record keeping, labour, and PPE. Costs may also involve capital acquisition expenses for transportation and/or spreading equipment, as well as expenses associated with site preparation (i.e., staging areas and or site access if not already established).

Given the nascent and/or relatively unpracticed aspect of applying wood ash on forest soils in Canada on a large scale, establishing 'costs' or 'value' is a complex exercise. Naturally, to fully evaluate cost modelling outcomes, one must understand the assumptions and parameters used in the model, and make adjustments for applicable realities.

The aim of this document is not to evaluate cost feasibility scenarios. However, for detailed insight into this subject matter, the reader is directed to A cost analysis of bioenergy-generated ash disposal options

[325] Hannam et al., 2016 (referencing Emilsson 2006; Skogsstyrelsen 2008)
[326] van Eijk. R.J Obernberger. I, Supancic. K, 2012
[327] Kim. N, Watmough. S, Yan. N, 2022
[328] Kim. N, Watmough. S, Yan. N, 2022 (referencing Jackson and Odom, 2021)

in Canada, Emily S. Hope, Daniel W. McKenney, Darren J. Allen, and John H. Pedlar, Canadian Journal of Forest Research, 2016. For additional cost perspectives see footnoted sources.[329]

Respective of associated assumptions and parameters of the study, the following conclusions were made in the report by Hope:

> *"Our findings indicate that, under average conditions, ash disposal in an existing producer-owned landfill is the most economically attractive disposal method. Alternatively, the costs of applying ash on forest sites are only slightly higher than those associated with disposal in an existing producer-owned landfill, suggesting that ash application on forest sites offers a viable alternative to the landfilling approach. Disposal in a municipal landfill and disposal in a newly constructed producer-owned landfill appear to be more costly options. However, given the wide range of outcomes identified here, selection of an appropriate ash disposal option will depend on the unique set of economic factors associated with a given bioenergy production facility."*[330]

## 3.14 Operational Challenges and Hurdles

At present, the operational challenges to recycling wood ash as a soil amendment are substantial. Much uncertainty exists around regulatory processes, ash supply, and ash quality. These uncertainties, as well as lack of knowledge among constituent stakeholders, are exacerbated by differences in regional realities. Collectively, and in the absence of clear economic incentives, these challenges impede the development of supply chains.

In many cases, the existence of one challenge exacerbates the reality of several others.

### 3.15 Regulatory Uncertainty and Complexity

Regulatory challenges pertaining to the use of wood ash as a soil amendment have already been covered in some detail in *2.9.1 The State of Wood Ash Use in Canada/Regulatory Situation*. The general theme of that section is succinctly captured in an assessment made by Hannam et al. (2018) in Wood ash as a soil amendment in Canadian forests: What are the barriers to utilization? "*The process of obtaining regulatory approval is challenging*."

Within the context of the Friends of the Muskoka Watershed's own experience operating a residential wood ash recycling program:

> "*Their biggest hurdles have been with the policy process of a wood ash recycling program. The approval process took much longer than initially thought, and it was not realized it could take months. Since this is a newly proposed soil amendment practice, approval for every step separately (collecting wood ash, storing the ash, transportation, and spreading) was needed,*

[329] **Lama. I, Sain. D, 2021 -** A case study review of wood ash land application programs in North America; **Nishio. G, Ersson. T, 2016** - Ash and Biosolids Spreading Trial, June 2016 – Technical Report No. 28; **Gaudreault. C, Lama. I, Sain. D, 2020** - Is the beneficial use of wood ash environmentally beneficial? A screening-level life cycle assessment and uncertainty analysis; **McElligott. K, Page-Dumroese. D, Coleman. M, 2011** - Bioenergy Production Systems and Biochar Application in Forests: Potential for Renewable Energy, Soil Enhancement, and Carbon Sequestration (Research Note); and **Ryan. M, 2000** - An evaluation of spreading mill biosolids in a forestry operation

[330] Hope. E. S, 2016

*which added extra time and money to the approval process. Every site the wood ash was added to required its own approval from the MECP before ash could be applied*."[331]

"*Every group expressed concern around the uncertainty of regulations for spreading wood ash in the forest. Without the proper policy process set by the government, this type of project will be challenging to make widespread."*[332]

A similar challenge J.D. Irving faced (see *2.5.2.1 Ash Uses/Land Application Programs – Canada*) was the cost and administrative burden of attaining provincial approval to land apply their ash on a site-by-site basis. As noted earlier in this report, this challenge was circumvented when the company obtained a federal fertilizer label from the CFIA.[333]

Regulatory challenges are not unique to Canada. As noted by Vance (2000) in reference to land application of wood ash within the U.S. pulp and paper industry: "*A second reason that some companies are reluctant to initiate a land application program is the time and cost associated with the permitting process…. This process is complicated by the fact that many states do not have regulations specific to land application and that more than one agency is often involved… Companies with land holdings spanning multiple states must also face disparate sets of regulations, requirements, and permitting procedures*."[334]

And, as noted in IEA Bioenergy's 2012 report Options for increased utilization of ash from biomass combustion and co-firing: "*the legislation on the utilization of biomass ashes for practical use as fertiliser is far from optimal." "The situation often leads to a complex approval procedure for the application of biomass ashes on soils which leads to delays, causing problems with potential users of the ash. Generally, the lack of sufficient legislation causes uncertainty for both plant operators and authorities*."[335]

## 3.16 Ash Volume (Supply) Uncertainty

Despite the actual and anticipated increase in biomass-based energy, and as noted in section 2.8 *Ash Volumes*, the amount of data regarding wood ash production is uncertain.

For organizations to invest in wood ash spreading operations, this gap in information will necessarily need to be addressed in order to verify potentially accessible supply.

To assess supply chain potential, ash volume data needs to account for the suitability of wood ash produced for land application in terms of quality (see *3.17 Uncertainty of Ash Quality*), with considerations for the potential seasonality of ash production, as well as location of production (see *3.19 Regional Differences*).

[331] O'Neill. K, 2022
[332] O'Neill. K, 2022
[333] NEBRA [North East Biosolids & Residuals Association], 2014 - From Liability to Asset: The J.D. Irving Agricultural Wood Ash Program
[334] Vance. E. D, 2000
[335] van Eijk. R.J Obernberger. I, Supancic. K, 2012

Understanding the seasonality of ash production is relevant when establishing ash volumes because larger volumes of ash are produced during the cold winter months, yet ash application is not recommended at that time due to ice and snow.[336] This has implications for storage requirements as well as predictability of ash supply volumes.

## 3.17 Uncertainty of Ash Quality

Fluctuating ash product quality is almost universally listed as a challenge to wood ash use as a soil amendment in relevant literature.[337]

Details and rationale regarding the suitability of ashes for use as a soil amendment have been covered in an earlier section of this document (*2.2 Wood Ash Chemistry*). Ash quality is of particular concern when plants mix biomass feedstocks with other feedstocks such as coal or industrial waste wood.[338] In these instances, the ash from biomass is at risk of being contaminated with hazardous elements and therefore rendered unusable as a soil amendment. This has implications for predictability of suitable ash supply.

Notwithstanding the issue of contaminated ash due to mixed feedstocks, ash composition differs greatly between different plants, and in many plants the quality of the ash also varies over time.[339] As noted earlier in this document, this is likely because the nature of ash is impacted by what is burned (plant and tissue type) as well as how it is burned (boiler type, temperature, etc.). Fluctuations in ash composition therefore necessitate diligent testing and continued regulatory oversight.

## 3.18 Lack of Knowledge

With regard to engaging in wood ash recycling activity for land application purposes, a common theme among relevant literature is the lack of awareness and/or lack of knowledge among constituent stakeholders, including government. The NCASI Fact Sheet Wood Ash as a Soil Amendment (Lama, 2022) makes this point:

> "*Some of the challenges associated with land application of wood ash include... misconceptions on the part of some land owners/ash users and government agencies regarding the effect and efficacy of wood ash on soil quality and crop productivity*."[340]

In Sweden, Bjurström and Herbert (2009) note that despite the first text on recycling or compensation with ash being issued in 1994, non-technical barriers to implementation included: Information not being made available or assimilated, and a lack of understanding between ash producers, fuel providers, and forest owners.[341]

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[336] van Eijk. R.J Obernberger. I, Supancic. K, 2012
[337] Bachmaier. H, Kuptz. D, Hartmann. H, 2021; Hannam. K.D et al., 2018; Pettersson. M, Björnsson.l, Börjesson. P, 2020; Pitman. R.M, 2006
[338] Pettersson. M, Björnsson.l, Börjesson. P, 2020
[339] van Eijk. R.J Obernberger. I, Supancic. K, 2012
[340] Lama. I (Dr.), 2022 - Fact Sheet: Wood Ash as a Soil Amendment
[341] Bjurström. H, and Herbert. R, 2009

In Germany, Bachmaier et al (2021) noted: *"A survey conducted under the AshUse-project showed that heating and plant operators often lack knowledge about quality management strategies, such as how a defined ash quality can be reliably maintained and verified."*[342]

It is notable that a common theme behind statements made by OPG in relation to their Atikokan biomass energy plant regarding '*key limitations to the increased diversion of wood ash from the waste stream'* is lack of knowledge. Stated limitations include:

- "*A need for demonstration and/or commercial proof of concept projects that can be used to illustrate the productive use of biomass ash and methods of avoiding or mitigating negative environmental impacts.*
- *Insufficient consumer demand for ash; a lack of understanding of its market value and the costs associated with transporting and processing ash for consumer-use.*
- *Lack of institutional confidence and know-how at the regulatory level on how best to manage ash in an environmentally safe manner."* [343]

Lack of knowledge was also highlighted by J.D. Irving. Among the early challenges the company faced when trying to get their wood ash (mill) residuals land-applied for agriculture, was 'limited end-use experience.' To get around this problem they hired an agricultural consulting company who helped them market the ash profitably, and educate farmers on how to increase crop production. Outreach activities included "*bringing booths and displays to farm meetings, hosting demonstration tour days in farmer's fields, getting ash approved for organic products, and incorporating it into their crop management plans.*"[344]

## 3.19 Regional Differences

As noted earlier in this report, transportation is a significant cost when considering the use of wood ash as a soil amendment. Therefore, the feasibility of a wood ash land application operation is limited by the distance between where ash is generated, and where it can be beneficially used. As such, supply chains must be local/regional in nature.

Additionally, soil 'needs' can differ by region adding complexity to regulations and/or best practices.

Regional differences in pre-conditions was listed as a non-technical barrier regarding the adoption of wood ash recycling in Sweden.[345]

As evidenced by the Domtar Windsor Mill's example, their wood ash recycling solution was engineered at the local level. While the Domtar corporation supports sustainability initiatives,[346] its sustainability solutions necessarily cannot be homogenized across all plants owned by the organization. This is likely the case for other conglomerates. As such, for more plants to participate in ash recycling activities, the

[342] Bachmaier. H, Kuptz. D, Hartmann. H, 2021
[343] Lamers et al., , 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[344] NEBRA [North East Biosolids & Residuals Association], 2014 - From Liability to Asset: The J.D. Irving Agricultural Wood Ash Program
[345] Bjurström. H, and Herbert. R, 2009
[346] Domtar, 2023 – Sustainability at Domtar

autonomy to seek out solutions must be enabled at the local/regional level, and the expertise and economic means must be available at the local/regional level.

## 3.20 Cost/Benefit Rationale

Under *traditional* economic paradigms, it is difficult to rationalize the additional expense and effort of recycling wood ash. Lack of economic incentive for all stakeholders was listed as a non-technical barrier regarding the adoption of wood ash recycling in Sweden.[347] Recycling is an additional cost for the ash producer as well as the landowner, and the latter is not to expect an immediate effect on growth.[348] O' Neill points out:

> "*Nutrient management is a long-term investment, and results may not be present right away, meaning companies may not want to take on that cost if it is not mandated.*"[349] "*…there is no immediate monetary benefit to fertilization, it is an investment… A company does not make money from a tree until it is fully grown…*"[350]

## 3.21 Supply Chain Issues

**Non-existent or Ineffectual Supply Chain**

In many parts of Canada and North America, wood ash recycling supply chains for land application purposes are scant, and in many regions they are virtually non-existent. This is rather predictable given the challenges already listed above.

As an example, OPG's biomass energy plant in Atikokan Ontario "*has had inquiries from parties interested in utilizing the ash, but cannot, at present, provide adequate and consistent volumes of ash to sustain a side-industry*."[351]

Other related comments in the literature include:

> *"Some of the challenges associated with land application of wood ash include... ineffective or inexistent coordination between facility representatives, ash users, trucking companies, and agrologists…"*[352]

> "*One of the problems that hampered ash use in Thunder Bay – until Resolute got the CFIA tag – was the lack of a certified NASM plan developer in the area.*"[353]

Regarding land application of wood ash within the U.S. pulp and paper industry, Vance (2000) pointed out that one reason why mills do not initiate land application programs is "*the logistic and technical difficulty associated with coordinating activities between the mill and forestry operations and with local*

[347] Bjurström. H, and Herbert. R, 2009
[348] Bjurström. H, and Herbert. R, 2009
[349] O'Neill. K, 2022
[350] O'Neill. K, 2022
[351] Lamers et al., 2018 (Chapter 5 Canada: Hannam. K, Emilson. C, Hazlett. P, Madrali. S, Mager. R)
[352] Lama. I (Dr.), 2022 - Fact Sheet: Wood Ash as a Soil Amendment
[353] Ford. R, 2019 – Ontariofarmer.com - Industrial Wood Ash is Popular in the Maritimes

*landowners and contractors*."[354] Vance went on to point out, "*This added coordination and planning places a burden on company managers and reduces the time available for their primary responsibilities*."[355] It would seem this issue has been somewhat alleviated since the Vance document was published in 2000. In a more recent document, Lama and Sain (2021) note that for agricultural land application programs in North America, *brokers* (or an agricultural service provider) typically connect ash generators (industry), to landowners (farmers) requiring ash for land application. This role can sometimes be undertaken by ash generators (i.e. Resolute, J.D. Irving), but typically brokers are third party companies that take on permitting/labeling responsibilities on behalf of the generator.[356]

**Number of Actors**

While supply chains are established in Sweden and Finland, Emilsson (2006) notes, "*one fundamental problem with the use of ash as a compensatory fertilizer on forest land is the number of actors involved in the chain from forest fuel extraction to application of stabilised ash*." Actors may include a combination of the following:[357]

- Landowners contracting forest fuel harvesting (timber and/or biomass removal)
- Forestry companies executing forest fuel extraction
- Intermediary suppliers/brokers of forest fuel, connecting forestry companies to plants requiring forest fuel
- Heating/energy/pulp and paper plants where forest fuel is combusted and ash is produced.
- Ash stabilizing contractors
- Ash application contractors (spreading ash on land/forest)

Emilsson details a few different scenarios that have emerged in Sweden and Finland including:

- In parts of Sweden the Swedish Forest Agency takes responsibility for organizing ash stabilization and application of ash on a contractual basis. Plants pay for the ash to be removed, and landowners pay a nominal fee to receive it.
- In some instances, plants have initiated and managed ash recycling directly.
- In several instances, forest fuel suppliers have engaged in ash recycling by returning it to their own forest, or to the land from which their forest fuel supply came.

## 3.22 Operational Opportunities

The obvious reason to engage in wood ash recycling and land application activity is for environmental and sustainability reasons. This document does not attempt to capture all the benefits of recycling wood ash from an environmental point of view; however, evidence is emerging that forest ecosystem resilience impacts green-house gas emissions, carbon capture, biodiversity, and perhaps even flood mitigation. These benefits have long-term, inestimable value for the sustainability of human life and human systems on the planet.

[354] Vance. E. D, 2000
[355] Vance. E. D, 2000
[356] Lama. I, Sain. D, 2021.
[357] Emilsson. S, 2006

While industry has become more and more responsive to sustainability concerns and is engaging in environmental stewardship activities which promote positive corporate image,[358] companies are typically driven by shorter-term motivations. As such, potential shorter-term - and more easily measured - benefits for ash generators include landfill cost savings, and revenue from wood ash sales.

## 3.23 Landfill Cost Savings for Ash Generators

As noted in section *2.6 The Cost of Landfill and The 'Circular Economy'* diverting wood ash waste away from landfill can potentially reap monetary benefits in the form of landfill cost savings for ash generators. Landfill cost considerations include disposal fees, the landfill's remaining life, ongoing maintenance and monitoring costs, and the eventual cost of commissioning a new site.[359] Gaudreault, Lama, and Sain (2020) point out: *"Like other beneficial uses, land application generally costs less than landfilling over its lifetime and can extend the life of company-owned landfills."*[360]

## 3.24 Revenue Potential For Ash Generators

The fact that wood ash supply in Nova Scotia is wait-listed would suggest that there is economic value of wood ash as a fertilizer. As noted by an agronomist in Nova Scotia, the fertility value of wood ash is estimated at $100-$150 per tonne. Local farmers in New Brunswick only pay for shipping charges, which in the case of one farmer is roughly $16-$17 per tonne.[361] Hébert and Breton (2008) point out: "*Since ash is a substitute for agricultural lime and mineral fertilizers, its value can be estimated based on the selling price for these competing materials.* [English translation]"[362] In a related comment, Lama (2022) points out: ash producers could potentially sell wood ash thereby adding a source of revenue.[363]

As noted in IEA Bioenergy's 2012 report: "*considering the fertilising value of the ash based on actual fertiliser prices and the average nutrient contents as well as the nutrient availability, the potential value of biomass ashes as fertiliser is considerable.*"[364]

### *3.24.1 Maple Syrup Production*

The impact of acid rain and subsequent calcium depletion of forest soils is particularly stressful for sugar maple trees because they have a particularly high calcium requirement compared with other native trees. As such, under stress, sugar maples growth is reduced, and they produce less sap and thus reduce the amount of maple syrup that can be produced from sap harvests. This is covered fairly extensively in academic journals. As noted by Kim et al. (2022), remediation of this problem can be managed by amending forest soils with wood ash:[365]

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[358] Forest Products Association of Canada, 2020 – Forest Certification in Canada: The Programs, Similarities and Achievements
[359] Ryan. M, 2000 - An evaluation of spreading mill biosolids in a forestry operation
[360] Gaudreault. C, Lama. I, Sain. D, 2020
[361] Ford. R, 2019 – Ontariofarmer.com - Industrial Wood Ash is Popular in the Maritimes
[362] Hébert. M, Breton. B, 2008
[363] Lama. I (Dr.), 2022 - Fact Sheet: Wood Ash as a Soil Amendment
[364] van Eijk. R.J Obernberger. I, Supancic. K, 2012 (referencing BIOS 2009)
[365] **For detailed information** on this subject see Kim. N, Watmough. S, Yan. N, 2022

> "*Wood ash addition and liming have been shown to increase sugar maple growth as the trees amass more woody tissue. In Quebec, amendment with IWA* [industrial wood ash] *at a relatively high dose (20 tons·ha−1) resulted in increased growth and basal area increment of mature sugar maples within 3 years. In other studies from Quebec, adding dolomite to a Ca deficient sugar maple stand led to significant improvements in soil chemistry, and liming a base-poor sugar maple stand improved sap sweetness and yield over the long-term*."[366]

Maple syrup producers have a vested interest in improving the soil health of the forests from which they produce maple syrup. Indeed, much of the work and study done by the Friends of the Muskoka Watershed regarding the recycling of wood ash on forest soil has been in close cooperation with multiple sugar bush owners in Ontario.

### 3.25 Carbon Credits

Nishio and Ersson (2016) point out: "*Adding ash to nitrogen-rich mineral soils that are medium-to-highly productive can increase tree growth for periods lasting 30 years or more. Any increased biomass growth that results from the spreading of ash on forest soils could be considered a form of carbon sequestration. A single tree could potentially sequester 160 kg of carbon over an 80-year period*."[367]

They go on to point out: "*If the addition of ash can be proven to increase tree growth, the application of ash for carbon credits is a valid claim. Establishing a valid credit for carbon sequestration requires the services of a consultant specializing in the carbon credit application process*."

Newer data suggest that the addition of wood ash on forest soils can increase C capture of 1 tonne/ha/year lasting for at least 20 years.[368]

## 4.0 CHAPTER 4 Making It Work: Systemic Considerations

Insights and recommendations have been made throughout relevant literature with regard to systemically improving the use of wood ash as a soil amendment. In many cases, these recommendations are in direct response to the challenges of using wood ash as a soil amendment previously described. We highlight these recommendations below.

Less abundant in the literature are recommendations that systemically address nutrient poor forest soils and neighboring watersheds that are legacies of historic acid rain. We provide some thoughts on this for consideration.

### 4.1 Recommendations to Encourage the Operational Use of Wood Ash as a Soil Amendment:

#### *4.1.1 Redefine or clarify the 'waste' paradigm as it pertains to wood ash*

The predominant historic and regulatory paradigm concerning wood ash is that it should be treated as a waste. As evident by the scope and nature of material contained in this document, shifting attitudes and

[366] Kim. N, Watmough. S, Yan. N, 2022 (referencing Arseneau et al. 2021; Houle et al. 2002; and Moore et al. 2020)
[367] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction (referencing Lindh et al., 2005; Roulet & Freedman, 1999)
[368] Taylor. L.L, Driscoll. C.T, Groffman. P.M, Rau. G.H, Blum. J.D and Beerling. D.J, 2021

behaviours in this regard requires scientifically verified information, clear regulatory pathways, guidelines on best practices, and supply chain infrastructure. However, prior to all of that, a will to initiate change on the part of governments is essential. And, it starts with language.

As noted in A Forest Bioeconomy Framework for Canada, "*The forest bioeconomy seeks to transform the Canadian economy by eliminating the landfilling of organic materials since these waste assets will be fully used as valuable inputs.*"[369] We suggest that the notion of 'waste assets,' within the context of the forest bioeconomy - and bioenergy in particular - be expanded to include biomass ash. We also suggest that the term 'waste assets' be replaced with a term that has more neutral or positive connotations.

An apparent motivation of the Swedish Ash Programme is illustrated in the following quote "*Combustion residues are usually thought of as waste, not resources, and there surely is nothing sustainable about waste? Waste is something to be managed, of course, but it is not a resource or one wouldn't have to discard it. A resource benefits one, but a waste is a cost or an obligation. This dichotomy between waste and resource has to be resolved if combustion residues are to find a place in a sustainable civilisation.*"[370]

IEA Bioenergy in its 2018 Task 32 Country Report (Lamers et al.) states: "*In a number of countries regulations do not allow recycling of wood ashes in the forests as it is seen as dispersion of waste; within the definition of use in forest, within that application the material is not seen as a fertiliser and therefore does not fall under the classification of biomass ashes under the fertiliser regulations. An allowance to use biomass ashes as soil amendment in forests and an end of waste classification of biomass ashes for this purpose would remove one of the bottlenecks for ash recycling*." [371]

### *4.1.2 Establish a more nimble regulatory infrastructure*

Regulatory infrastructure was frequently mentioned in the literature as a significant barrier to recycling wood ash as a soil amendment (see *2.9.1 The State of Wood Ash Use in Canada/Regulatory Situation;* and *3.15 Operational Challenges and Hurdles/Regulatory Uncertainty and Complexity*). Given the nature of wood ash and the differences in soil conditions from site to site, regulatory oversight will likely continue to be required. However, approval processes need to be streamlined, and at the least, more clearly established. Indeed in some instances, (such as Ontario/Crown forest land), the forbiddance to apply wood ash to forest soils should be reconsidered.

The route that some ash generators in Canada have taken to certify their ash via the CFIA or the BNQ (see *2.9.2 Regulatory Workaround: Ash Certification as a Fertilizer or Liming Material*) has expedited the use of wood ash as a fertilizer and increased its use in agricultural settings. A similar regulatory route is available in Germany (see *2.10.2 International Picture/Germany*) and is augmented by a quality label.

As noted earlier in this document (2.10.5 *International Picture/United States*), in the state of New Hampshire wood ash can be listed as a 'certified waste-derived product.' In accordance with the terms

[369] Canadian Council of Forest Ministers (CCFM), 2017 - A Forest Bioeconomy Framework for Canada
[370] Bjurström. H, and Herbert. R, 2009
[371] Lamers et al., 2018

and conditions of its certification as well as its associated intended use, a certified waste-derived product is no longer regulated as a solid waste.

Specific details around how wood ash recycling is regulated in Finland and Sweden – where wood ash recycling has been promoted for several decades - were not uncovered in this literature search likely due to language barriers. If possible, this avenue of learning should be explored further.

A corollary to improving the regulatory process would be greater integration between government policy and the science community. This was noted in a webinar conducted by Paul Hazlett of the GLFC in 2016.[372]

While we recognize that the Bioeconomy Technical Working Group in Ontario (see *2.9.4.2. The State of Wood Ash Use in Canada/Ontario/Bioeconomy Technical Working Group*) – if it continues to exist - might be an ideal forum for this kind of work/integration in Ontario, we note that given the classification of wood ash as a waste, collaboration might benefit from the inclusion of the MECP.

### *4.1.3 Standardize sampling and testing procedures for soil and ash assessment*

As part of the regulatory process, providing standardized sampling and testing procedures across multiple jurisdictions would ease uncertainty and administrative burden for ash generators and ash users.

Stupak et al. (2008) points out that "*Sampling errors are believed to be the major source of uncertainty when wood ash is sampled to determine its quality."* Stupak et al. go on to say that: *"… a common standard method and use of accredited laboratories would therefore be preferable to avoid incorrect and incomparable analytical results*." [373]

Leveraging contextual learning from pulp and paper mill wood ash land application [agricultural] programs in North America, Lama and Sain point out:

"*Some facilities and brokers have found it difficult to ensure that the correct ash testing procedures are used and that appropriate testing requirements are met. This is often the result of requirements that are set on a case-by-case basis or are jurisdiction-specific. Adoption of a permitting approach that employs more uniform requirements across multiple jurisdictions would allow companies and brokers to standardize their ash testing procedures and ensure testing requirements are always met. This approach would likely result in a larger number of successful land application programs*."[374]

### *4.1.4 Assess current and/or anticipated ash volumes*

For supply chains to emerge and the prospect of using wood ash as a soil amendment to be feasible, a clearer understanding of how much ash is produced regionally across Canada is required. As mentioned in section *3.16 Ash Volumes (Supply) Uncertainty*, data of this nature needs to account for location, seasonality, and general quality of ash produced (i.e., clean or contaminated).

[372] Hazlett. P, 2016
[373] Stupak et al., 2008
[374] Lama. I, Sain. D, 2021

Ash volume data would require understanding volumes of ash produced at pulp and paper mills, lumber mills, and operations where heat and/or electricity is derived from biomass (woody fibre) fuel.

### *4.1.5 Provide systemic incentives to improve wood ash quality*

As pointed out by Hannam et al., (2017): "*to our knowledge, no guidance has been developed to strategically manipulate the quality of Canadian wood ash*."[375]

Improving the quality of wood ash really means, reducing the volume of wood ash that is unusable due to contaminated feedstocks. It is a common theme throughout relevant literature. Nishio and Ersson (2016) point out: "*Clean feedstocks and contaminated feedstocks are generally not sorted to be burned separately, but if ash generators have an incentive, they should be able to separate the dirty feedstocks from the clean forest biomass and burn them at different times (or at different locations.)"*[376]

Nishio and Ersson (2016) go on to explain: *"When ash is intended for agricultural land application, ash generators in New Hampshire and Maine burn only clean feedstocks. Contaminated feedstocks (industrial waste, tires, etc.) are burned separately from clean feedstocks or are burned in different facilities, and the contaminated ash is disposed of in landfills. Repeated chemical testing along with government monitoring over several years has allowed the ash generators to sell ash for land application without further testing as long as the feedstocks are documented to be from clean forest material."*[377]

As noted earlier in this report, the low suitable quality of wood ash for forest soil recycling purposes in Sweden is an outcome of forest fuels being co-incinerated in heating and power plants with other, cheaper forms of 'waste' wood that often contain toxic compounds. Pettersson, Björnsson, and Börjesson (2020) explain: "*The considerable difference in price between logging residues and waste wood is the main reason for the recent increase in the use of waste wood [in bioenergy production*]."[378]

As prescribed by the German Fertilizer Ordinance, only untreated wood should be used in biomass heat (and power) plants, since waste wood can contain elevated concentrations of heavy metals.[379] Emilsson (2006) affirms: "*…even small amounts of contaminated fuel fractions will cause high concentrations of heavy metals in ash.*"[380]

In order to fully leverage the potential of biomass ash as an agricultural or forest soil amendment, contamination of biomass feedstocks with waste wood (or other) contaminating feedstocks should be avoided.[381] The logistical and economic feasibility of this for ash producers (energy, pulp and paper) should be reviewed given that changes in price and availability of fuels is variable.[382]

[375] Hannam et al., 2017
[376] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[377] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[378] Pettersson. M, Björnsson.l, Börjesson. P, 2020
[379] Bachmaier. H, Kuptz. D, Hartmann. H, 2021
[380] Emilsson. S, 2006
[381] van Eijk. R.J Obernberger. I, Supancic. K, 2012
[382] van Eijk. R.J Obernberger. I, Supancic. K, 2012

### *4.1.6 Develop and refine wood ash application methods and supply chain logistics at scale*

For wood ash applications in forest settings to be meaningfully addressed, operational logistics and application methods – beyond buckets and shovels – need to be experientially studied and refined in Canada. Emilson et al., (2018) points out: "*Future research needs to build on the current operational scale methods being utilized (e.g. in Europe and in southern Quebec) to refine larger scale application methods for use across Canada*."[383]

At the site level, learning can be leveraged from the Domtar Windsor Mill experience in Quebec. At both the site and supply chain level, learning can be leveraged from Finland, Sweden, and possibly other European countries such as Germany. Additionally, relevant supply chain learning may be drawn from agricultural land application programs in Canada and the United States.

### *4.1.7 Expand awareness, knowledge sharing activities, and breadth of collaboration*

The motivation to do anything of a substantive nature first requires awareness and knowledge. A meaningful amount of academic material has been produced regarding the use of wood ash as a soil forest amendment. And, its operational and environmental efficacy has been demonstrated in the Nordic countries. Yet, outside some instances of agricultural use, the momentum to allow or use wood ash as a forest soil amendment appears to be lacking in Canada despite the anticipated increase in the production of biomass ash via biomass energy.

The Swedish Forest Agency (Skogsstyrelsen) noted that while it had been recommended (in 1998) to recycle wood ash in forests where harvesting residues had been/or would be removed, after a number of years the amount of recycling with ash was below expectations. The Swedish Forest Agency's assessment of the situation was that 'lack of knowledge' was the main factor preventing the practice from being more widely implemented.[384]

Knapp and Insam (2011) noted this as an issue elsewhere in Europe: *"Whereas wood ash application in forest ecosystems is commonly accepted in Northern European countries, this is not so in other European countries. It is thus necessary to increase public awareness of the importance of sustainable forest management including the recycling of wood ashes."*[385]

In Canada, for policies to change, supply chains to emerge, less 'beneficial waste' going into landfills, and for harvested forests to be replenished with removed biomass nutrients via wood ash, more awareness and motivation to participate among government and industry stakeholders is required.

In the absence of clear regulatory pathway at his juncture, the development of educational materials as well as broader promotion and collaboration is recommended in the shorter term in order to resolve the existing challenges and hurdles impeding the use of wood ash as a forest soil amendment at scale.

We note the following comment in the CCFM's report on Forest Sector Innovation in Canada 2015, White Paper: Opportunities for the Canadian Council of Forest Ministers, 2015 (Lesson #6) regarding

[383] Emilson. C et al, 2018
[384] Swedish Forest Agency (Skogsstyrelsen), 2006 - Regular Recycling of Wood Ash to Prevent Waste Production: RecAsh - A Life-environment demonstration project (Layman's Report)
[385] Knapp. B, and Insam. H, 2011

'receptor capacity' within Canadian forestry companies particularly at the mill level relative to international competitors. The context for this comment specifically references 'innovation receptor capacity' and states that: "*there are insufficient individuals within forest sector companies with the mandate, skill, training, and education to monitor RDD&D and identify where such activities can best be deployed within their company*."[386]

While this comment is quite specific, we find it relevant considering that in the longer-term, deploying wood ash forest soil recycling programs is necessarily a local/regional endeavour that will require degrees of process development at the mill level. As such, knowledge sharing support and promotion will need to consider and accommodate for needs at this level.

### *4.1.8 Consider economic incentives to encourage engagement*

In monetary terms, it is difficult to place the value of activity associated with improving environmental sustainability on a balance sheet. Yet ensuring the sustainability of our environment - including forests and watersheds - is fast approaching a societal *need* rather than a societal *value*.

Helping industry engage in more sustainable processes and activities with incentives that are meaningful on a balance sheet may encourage interest and engagement among industry stakeholders.

As demonstrated by the pulp and paper industry, a key motivator in exploring alternative disposal methods for wood ash has been the increasing costs to landfilling. Yet as noted, by Nishio and Ersson (2016) "r*elatively inexpensive landfill sites for ash are still available to many wood ash producers in Canada, so the motivation to change from the current practice of landfilling most ash is not strong*."[387]

In exploring the benefits of using wood ash as a forest soil amendment and the current hurdles causing the process to be slowed down, O'Neill (2022) reported cost as being a common concern expressed by participants. The following suggestions were made:

> "*There were a few solutions to this issue, with the first being trust funds from forest companies. These trust companies were not built for long-term soil reclamation but would be a starting point for forestry organizations*."[388]
>
> "*Subsidies or tax breaks could also be a possible solution to the cost issue.*"[389]

A similar suggestion to the second point could be leveraging or adjusting the fulcrum of royalties paid by lumber companies to government in exchange for harvesting timber from public lands.

[386] Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation In Canada (2015): White Paper: Opportunities for the Canadian Council of Forest Ministers
[387] Nishio. G, Ersson. T, 2016 - Spreading Wood Ash on Forest Land in Canada: An Introduction
[388] O'Neill. K, 2022
[389] O'Neill. K, 2022

## 4.2 Recommendations to Address Nutrient-poor Forest Soils and Watersheds Due to a Legacy of Acid Rain on Forest Soils and Watersheds

### *4.2.1 Revisit paradigms of 'forest health' and 'sustainability'*

As noted by Puddister et al. (2011), the Crown Forest Sustainability Act [Ontario] defines sustainability as "*long term Crown forest health*."[390]

Long term protection of Canada's forest requires a viewpoint of sustainability that includes soil health and neighboring forest watershed health. Paradigms of forest health and sustainability should not only aim to 'protect' what exists, but it should also aim to restore – where feasibly possible – that which has been damaged by human industry.

In its Policy Framework for Sustainable Forests published in 1994, the Government of Ontario stated the following:

- *"It is crucial, however, that we see forests as ecosystems, not just trees."*
- *"Forest ecosystems, while dominated by plants called trees, also include shrubs, herbs, mammals, birds, microscopic creatures, soil, air, water, and other components of nature"*
- *"Maintaining ecological processes is essential for the functioning of the biosphere, and biological diversity must be conserved in the use of forest ecosystems."*[391]

OPG's Biomass Sustainability Analysis published in 2011 stated that: "…*harvesting forest biomass for electricity production must be done in a way that protects ecosystems*." In that report, sustainability criteria for harvesting biomass recognized (in addition to forest site productivity), soil quality, hydrology and water quality, biodiversity and terrestrial habitats.[392]

In A Shared Vision for Canada's Forests: Toward 2030, (published in 2019), the Canadian Council of Forest Ministers (CCFM) included the following statements:

- "*Sustainable forest management is a way of caring for forests to maintain their benefits over time*."[393]

- "*Forests are complex ecosystems, providing clean air, fresh clean water, soil production, carbon storage, pollination, habitat for plants, animals and fungi, and more.*"[394]

As stated in that report, the CCFM's vision is that: "*Canada' sustainable forest management practices maintain resilient, healthy forests that support vibrant communities, stronger collaborations with Indigenous people and competitive economies.*"[395] A stated goal of the CCFM published in that report is:

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[390] Puddister. D, Dominy. S.W.J, Baker. J.A., Morris. D.M, Maure. J, Rice. J.A, Jones. T.A, Majumdar. I, Hazlett. P.W, Titus. B.D, Fleming. R.L,Wetzel. S, 2011

[391] Government of Ontario, Ministry of Natural Resources, Forests Division,Forest Management Branch, Forest Policy Section, 1994 - Policy Framework for Sustainable Forests

[392] Pembina Institute (for Ontario Power Generation), 2011 - Biomass Sustainability Analysis: Summary Report 2011

[393] Canadian Council of Forest Ministers, 2019 - A Shared Vision for Forests in Canada: Toward 2030

[394] Canadian Council of Forest Ministers, 2019 - A Shared Vision for Forests in Canada: Toward 2030

[395] Canadian Council of Forest Ministers, 2019 - A Shared Vision for Forests in Canada: Toward 2030

"*We aspire to increase forest resiliency and the amount of carbon stored in forests and wood products*."[396]

These policy statements recognize the interconnectedness of trees with larger ecosystems, and the importance of forest ecosystem health. Yet, 'forest health reports' such as the Forest Health Conditions Report (2020) published in Ontario, while focusing on the impact of pests, disease, forest fire, and blowdown on Ontario forests, do not monitor forest soil quality or related ecosystem health:

> *"Forest health monitoring in Ontario includes the occurrence of biotic (e.g., insects, disease) and abiotic (e.g., snow and drought damage) disturbances and events. All forested area in the province, regardless of ownership, is monitored and reported on each year*."[397]

In The State of Canada's Forests Annual Report 2021, the message from the Honorable Jonathan Wilkinson, Minister of Natural Resources, Canada points out:

> *"As Canada's forest face the realities of a changing climate and biodiversity loss, researchers are working to mitigate the effects of natural disturbances, such as forest pests and wildland fires, to ensure the long-term protection of our environment. Research and innovative forest and land management practices will help protect our forests and the many benefits they provide to Canadians." [398]*

We note that soil health and forest health issues pertaining to calcium depletion and historic acid rain are not mentioned.

Kim et al. (2022) corroborate: "*Calcium limitation is currently not included in Canada's national agenda as a cause of forest decline (State of Canada's Forests 2020), but our review of the literature suggests that it should be*."[399]

While review of biomass harvesting policy in Canada is not the intent, nor within the scope of this document,[400]we note, as a leading example, the degree to which biomass harvesting policy in the province of New Brunswick considers soil health and yield potential:

"*In the Policy [New Brunswick's Crown Land Forest Biomass Harvesting Policy], a forest stand's eligibility for biomass harvesting is determined with the GIS-based Forest Biomass Decision Support System, which uses the most current information available relating to soils, climate, and forest growth and yield. The model uses soil type, bedrock type, atmospheric nutrient deposition, and tree nutrient content information to calculate the total nutrient supply for a forest stand. Nutrient demand is also calculated, using information about forest composition and associated stand growth. The impact of removing biomass on forest growth is then calculated as the total available nutrient supply minus the nutrient demand to sustain a pre-defined growth rate of a given stand. The GIS-based information is verified and*

[396] Canadian Council of Forest Ministers, 2019 - A Shared Vision for Forests in Canada: Toward 2030
[397]Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, Science Research Branch, 2020 - Forest Health Conditions in Ontario, 2020
[398] Natural Resources Canada, 2021 - The State of Canada's Forests Annual Report 2021
[399] Kim. N, Watmough. S, Yan. N, 2022 (referencing State of Canada's Forests 2020)
[400] **For a comprehensive review** of biomass harvesting policy in Canada see Roach. J, Berch. S.M, 2014

*combined with information collected on the ground including soil depth, depth to water table, and current stand conditions, and all of the information is used together to assess biomass sustainability*."[401]

### *4.2.2 Within the context of biomass energy development, consider a more fulsome circular economy that includes recycling wood ash to forest soils*

As governments and industry develop biomass energy markets in Canada, closing the sustainability loop by returning biomass ash to forest soils should be encouraged – particularly to forest soils impacted by historic acid rain.

The government of Ontario recently published its Forest Biomass Action Plan:

> "*The goals of the Forest Biomass Action Plan are to secure jobs, support economic development, and encourage sustainability in the forest sector through the use of Ontario's forest biomass. To support these goals, we have identified five objectives, each with a set of actions that will be pursued over the five-year term of this action plan*:
>
> - *Objective 1: Identify pathways to markets for forest biomass.*
> - *Objective 2: Support demand for forest bioenergy and bioproducts.*
> - *Objective 3: Improve the business and regulatory environments for the use of forest biomass.*
> - *Objective 4: Support holistic, culturally relevant pathways for Indigenous community involvement in forest biomass value chains to support reconciliation between Indigenous communities and the Crown.*
> - *Objective 5: Communicate, collaborate, and inform on forest biomass opportunities.*[402]

We note that consideration for wood ash as a by-product of biomass energy production is not mentioned, nor is the potential to benefit forest soils and close the 'circular economy loop' by using wood ash as a forest soil amendment.

That said, we do note that 'soil quality' and long-term ecological sustainability is mentioned as a consideration for research studies in another area of that report:

> "*Conduct collaborative research studies on soil quality, stand development, productivity, and biodiversity to ensure long-term ecological sustainability of forest biomass harvesting to inform policy under Ontario's Policy Framework for Sustainable Forests.*" [403]

As noted in IEA Bioenergy's 2018 report: *"In preparation for a future in which bioenergy provides a larger fraction of the electricity mix and produces greater volumes of ash, alternative uses for biomass ash need to be considered. Greenhouse gas emissions aside, the use of bioenergy will be far more sustainable if ash is used beneficially."*[404]

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[401] Roach. J, Berch. S.M, 2014

[402] Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, 2022 – Forest Biomass Action Plan

[403] Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, 2022 – Forest Biomass Action Plan

[404] Lamers. F. et al., 2018

Given the value of wood ash to return nutrients to soils and/or correct deficiencies in forest soils and watersheds due to historic acid rain, it follows then that to more fulsomely close the loop on the circular economy and 'squeeze the maximum value out of every tree,' recycling wood ash on forests soils should be encouraged.

### *4.2.3 Ensure that differences in eco-zone realities pertaining to soil health and watershed health are not overlooked in policy development*

As noted by Roach and Berch: "*All of the provinces and some of the territories have some sort of ecological classification system for their forests and this allows for ecosystem-based management, whereby management interpretations can be developed on an ecosystem basis, although site-specific conditions and situations must always be considered. The degree to which ecological classification is used in management varies among jurisdictions.*"[405]

A region of Ontario particularly affected by historic acid rain is the Georgian Bay (5E) Ecoregion. The Georgian Bay Ecoregion is situated on the southern portion of the Precambrian Shield, in south-central Ontario, extending from southeastern Lake Superior in the west to the central portion of the Ottawa River valley and the Quebec border in the east. It encompasses almost 7.5 million hectares (7.5%) of the province.[406]

According to a 2009 Ministry of Natural Resources, Ontario document referencing Environment Canada, 1988 "*Three quarters of the substrates in the [5E] ecoregion demonstrate low capacity to buffer the impacts of acidic precipitation*."[407]

The Georgian Bay 5E Ecoregion is embedded within the Great Lakes-St. Lawrence forest region noted at the beginning of this document. Within the Georgian Bay 5E Ecoregion lies the District Municipality of Muskoka. While the impact of historic acid rain is not exclusive to the District Municipality of Muskoka, the district alone represents close to 650,000 hectares (8.7%) of the Georgian Bay Ecoregion and is home to 1600, lakes and 19 quaternary watersheds.

As noted by Kim et al. (2023) "*Human-induced Ca declines can threaten the health, structure, and functioning of forests, thereby negatively affecting the critical ecosystem services they offer including water filtration, oxygen production, and nutrient cycling*."[408]

Within the context of biomass harvesting policy**,** as noted by Hannam et al. (2018), biomass harvesting can exacerbate issues associated with calcium depletion due to acid rain:

"*Atmospheric sulphur and N deposition has led to severe acidification of surface waters and soils and depletion of soil base cation pools on acid-sensitive sites in central Europe and northeastern North America. This phenomenon has been shown to alter lake ecology and has raised concerns that soils and forests on basepoor sites have been rendered more sensitive to biological acidification caused by nutrient*

[405] Roach. J, Berch. S.M, 2014
[406] Government of Ontario, Ministry of Natural Resources: Crins. W. J, Gray. P.A, Uhlig. P.W.C, Wester. M.C.Crins. W. J, Gray. P.A, Uhlig. P.W.C, Wester. M.C., 2009
[407] Government of Ontario, Ministry of Natural Resources: Crins. W. J, Gray. P.A, Uhlig. P.W.C, Wester. M.C.Crins. W. J, Gray. P.A, Uhlig. P.W.C, Wester. M.C., 2009 (referencing Environment Canada, 1988)
[408] Kim. N, Watmough. S, Yan. N, 2022 referencing Schaberg et al 2001)

*removals associated with timber and biomass removal. According to a recent meta-analysis (of predominantly European and North American studies), biomass harvesting can lower the pH and base saturation of surface soils and reduce concentrations of foliar calcium in the regenerating stand, but only when foliage is removed along with tree stems and branches. Research has shown that applications of wood ash can be used to increase soil pH and base saturation, thereby increasing surface water pH, which, in turn, may facilitate the ecological recovery of surface waters."*[409]

As biomass harvesting research and policy is developed and refined in Canada, particularly in Ontario and other provinces with nutrient poor forests impacted by acid rain, it is imperative that the differences in forest and watershed realities between eco-zones be accounted for.

### *4.2.4 Prioritize applied research on a catchment scale*

As demonstrated by the work being done by AshNet and its constituent contributors, the science community continues to study various aspects of wood ash as a forest soil amendment in Canada. In a summary of the work being done by AshNet, Emilson (2018) made experimental design and measurement recommendations. Among them was a recommendation to conduct experiments at the watershed or catena level in order to more thoroughly assess aquatic impacts.[410]

Kim et al. (2022) note: "*Currently, little information is available regarding the effects of wood ash additions on downstream surface waters and aquatic biota." "To our knowledge, very few studies have demonstrated a benefit of wood ash addition to lakes and streams, and this is likely due to a lack of ash addition field trials at the catchment scale*."

Practically speaking, we note that funding for this kind of work, especially done in the Great-Lakes St Lawrence Forest area affected by acid rain, would more demonstrably inform the issue of calcium deficiency in forest soils and watersheds presented by the Friends of the Muskoka Watershed and its academic partners. Study at a catchment scale would also provide measurable insights regarding impacts on carbon capture, flood mitigation, maple syrup production, wood production, and ecosystem health.

## Conclusion

Framing the state of industrial wood ash use as a forest soil amendment - or a potential forest soil amendment - necessarily requires the inclusion of several relevant dynamics including:

- The rise of energy derived from biomass and the implications this has regarding:
    - the nutrient sustainability of forests – and by extension watersheds and ecosystems - where biomass has been removed; particularly forests or ecosystems already suffering from malnutrition due to historic acid rain
    - the anticipated increase in wood ash volumes, and the legacy of its disposal via landfill

[409] Hannam. K.D et al., 2018 (referencing (Driscoll et al. 2003; Canadian Council of Ministers of the Environment 2008; European Environmental Agency 2012; Watmough et al. 2003; Jeziorski et al. 2008; McLaughlin 2014; Lofgren et al. 2017; Achat et al. 2015; Westling and Zetterberg 2007; Johansson 2014; Huotari et al. 2015).
[410] Emilson. C et al, 2018

- The experience of the pulp and paper sector regarding land application of wood ash/mill residuals as a soil amendment in agricultural settings
- The differences in realities across countries and in some cases regions due to:
    - Regulatory differences and/or complexity
    - Ash production and/or ash quality
    - Forest health realities
- Systemic challenges spanning logistic, economic, and knowledge areas

Driving the vision behind much of the work already done by others on this topic is the underlying desire to move society forward in terms of valuing and appropriately using natural resources so that local and global natural environments and ecosystems can thrive.

Reducing waste, replenishing what we have damaged or taken, pursuing circular economies, and ensuring our actions do not compromise the ability of future generations to meet their own needs… these ideals have graduated from goals that we might have had a few decades ago, to becoming essential obligations and responsibilities that citizens, governments, and industry must collectively uphold today.

Finding optimal ways to systemically leverage the nutrient value of industrial wood ash and apply it to forest soils where biomass has been harvested and/or soils and watersheds have been damaged by human activity (historic or otherwise) requires collaboration among many stakeholders. Developing and sharing a framework of understanding around the state of industrial wood ash use is a means to foster knowledge, fuel collective awareness, and drive communication, participation, and will.

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## References

**Agriculture and Agri-foods Canada**. Biochar can turn plant waste into healthy soils and improve the environment. From website https://agriculture.canada.ca/en/news-agriculture-and-agri-food-canada/scientific-achievements-agriculture/biochar-can-turn-plant-waste-healthy-soils-and-improve-environment (January, 2023)

**Alberta Environment**. Standards and Guidelines for the Use of Wood Ash as a Liming Material for Agricultural Soils. Government of Alberta, 2002

**Bachmaier. H, Kuptz. D, Hartmann. H**. Wood Ashes from Grate-Fired Heat and Power Plants: Evaluation of Nutrient and Heavy Metal Contents. Sustainability 13, no. 10: 5482. 2021. https://doi.org/10.3390/su13105482

**Beltrami SWCD** [Minnesota, USA] Wood Ash Program Instructions. From website www.co.beltrami.mn.us (January, 2023)

**Bjurström. H, and Herbert. R**. The Swedish Ash Programme 2002-2008: Biomass, wastes, peat - any solid fuel but coal, A synthesis of the Ash Programme in English. VÄRMEFORSK Service AB, July 2009.

**British Columbia, Ministry of Environment (prepared by Sylvis Environmental).** Land Application Guidelines for the Organic Matter Recycling Regulation and the Soil Amendment Code of Practice. 2008 https://www2.gov.bc.ca/assets/gov/environment/waste-management/waste-discharge-authorization/guides/land_application_guildlines.pdf

**Bureau de normalisation due Quebec (BNQ)**. Norme BNQ 0419-090 Amendements minéraux – Amendements calciques ou magnésiens provenant de procédés industriels. 2022. https://www.bnq.qc.ca/fr/normalisation/environnement/amendements-calciques-ou-magnesiens.html

**Burelle. S, Beaulieu. R, St-Laurent. S.** Guide sur l'utilisation de matières résiduelles fertilisantes (MRF) pour la restauration de la couverture végétale de lieux dégradés: Critères et exigences. Développement durable, Environnement et Parcs. Quebec, 2005

**Campbell. A.G.** Recycling and disposing of wood ash. Tappi Journal, September, 1990

**Canada Energy Regulator [Government of Canada].** Canada Energy Regulator, Market Snapshot: Canadian wood pellet exports grew 46% between 2015 and 2016. Release date: 2017-11-15. https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2017/market-snapshot-canadian-wood-pellet-exports-grew-46-between-2015-2016.html#:~:text=The%20primary%20destinations%20for%20Canadian,exported%20to%2011%20other%20countries.

**Canadian Council of Forest Ministers** (CCFM). A Forest Bioeconomy Framework for Canada. 2017. https://www.ccfm.org/wp-content/uploads/2017/08/10a-Document-Forest-Bioeconomy-Framework-for-Canada-E.pdf

**Canadian Council of Forest Ministers** (CCFM). Forest Sector Innovation In Canada (2015): White Paper: Opportunities for the Canadian Council of Forest Ministers. https://www.ccfm.org/wp-content/uploads/2020/08/White-Paper-Opportunities-for-the-CCFM.pdf

**Canadian Council of Forest Ministers**. A Shared Vision for Forests in Canada: Toward 2030. 2019. https://www.ccfm.org/releases/a-shared-vision-for-forests-in-canada-toward-2030/

**Canadian Food Inspection Agency.** Guide to Submitting Applications for Registration under the *Fertilizers Act (New Regulations). 2020.*

**Canadian Food Inspection Agency**. List of Primary Fertilizer and Supplement Materials. From website https://inspection.canada.ca/plant-health/fertilizers/regulatory-modernization/list-of-primary-fertilizer-and-supplement-material/eng/1533213691120/1533213691867 (January 2023)

**Cherian. C, Siddiqui. S**. Pulp and Paper Mill Fly Ash: A Review. Sustainability 2019, 11(16), 4394; https://doi.org/10.3390/su11164394

**Couch. R.L, Luckai. N, Morris. D, Diochon**. A. Short-term effects of wood ash application on soil properties, growth, and foliar nutrition of Picea mariana and Picea glauca seedlings in a plantation trial. Canadian Journal of Soil Science. December 18, 2020. 101(2): 203-215. https://doi.org/10.1139/cjss-2020-0105

**de Jong. J, Akselsson. C, Berglund. H, Egnell. G, Gerhardt. K, Lönnberg. L, Olsson. B, von Stedingk. H.** Consequences of an increased extraction of forest biofuel in Sweden: A synthesis from the bioenergy feedstock research programme 2007-2011, supported by Swedish Energy Agency. IEA Bioenergy Task 43, Report 2014:01

**Domtar** [commercial]. Windor Mill's Circular Economy Reduces Waste. June 14, 2018. From website: https://newsroom.domtar.com/windsor-mill-circular-economy/

**Domtar** [commercial]. Sustainability at Domtar. From website: https://www.domtar.com/en/how-we-work/sustainability-domtar (January, 2023)

**Duinker. P.** Society's Forest Values. Report #11 in the Series on "Drivers of Change in Canada's Forests and Forest Sector", prepared for the Forest Futures Project of the SFM Network, University of Alberta, 2008. https://doi.org/10.7939/R3862BC7M

**Elliott. A, Mahmood. T.** Beneficial uses of pulp and paper boiler ash residues. TAPPI JOURNAL, Vol 5. No 10: October 2006

**Emilson. C, Hannam. K, Aubin. I, Basiliko. N,** Bélanger. N, Brais. S, Diochon. A, Fleming. R, Jones. T, Kabzems. R, Laganière. J, Markham. J, Morris. D, Rutherford. M, Rees. K, Venier. L, Webster. K, Hazlett. P. Synthesis of Current AshNet Study Designs and Methods with Recommendations towards a Standardized Protocol. 2018. Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre. https://www.researchgate.net/publication/328744185_Synthesis_of_Current_AshNet_Study_Designs_and_Methods_with_Recommendations_towards_a_Standardized_Protocol

**Emilson. C.E., Bélanger. N, Brais. S, Chisholm.C.E, Diochon. A, Joseph. R, Markham. J, Morris. D, Van Rees. K, Rutherford. M, Venier. L.A, Hazlett. P. W.** Short-term growth response of jack pine and spruce spp. to wood ash amendment across Canada. GCB-Bioenergy, Volume 12, Issue 2, February 2020. https://doi.org/10.1111/gcbb.12661

**Emilsson. S.** From Extraction of Forest Fuels to Ash Recycling: International Handbook. Skogsstyrelsen (Swedish Forest Agency), 2006

**Ford. R.** Industrial wood ash is popular in the Maritimes. Dec 20, 2019. From website Ontariofarmer.com

**Forest Products Association of Canada (FPAC)**. Forest Certification in Canada: The Programs, Similarities and Achievement. May 2020, https://www.fpac.ca/reports/forest-certification-in-canada-the-programs-similarities-achievements

**Forest Products Association of Canada (FPAC**). Canada's Green Economy Grows In Canada's Forests. From website: https://www.fpac.ca/story (January, 2023)

**Forest Products Association of Canada (FPAC).** Innovative, Sustainable, Resilient: Recommendations from Canada's forest sector to drive economic recovery and a net-zero carbon future. 2020. https://www.fpac.ca/reports/innovative-sustainable-resilient-forest-products-association-of-canada-recommendations-from-canadas-forest-sector-to-drive-economic-recovery-and-a-net-zero-carbon-future

**FPInnovations.** Who we are**.** From website https://web.fpinnovations.ca/who-we-are/ (January, 2023)

**Friends of the Muskoka Watershed.** Residential Wood Ash Recycling and Forest Soil Amendment: Operations Guide. 2021. By permission.

**Friends of the Muskoka Watershed.** About AshMuskoka. From website https://fotmw.org/about-ashmuskoka/ (January, 2023)

**Gaudreault. C, Lama. I, Sain. D.** Is the beneficial use of wood ash environmentally beneficial? A screening-level life cycle assessment and uncertainty analysis. Journal of Industrial Ecolology. 2020; 24: 1300– 1309. https://doi.org/10.1111/jiec.13019

**Government of Canada.** Circular Economy. From website: https://www.canada.ca/en/services/environment/conservation/sustainability/circular-economy.html (January, 2023)

**Government of New Brunswick, Department of Agriculture, Aquaculture, and Fisheries**. Funding to support soil productivity and sustainability project (News Release). 2021. https://www2.gnb.ca/content/gnb/en/departments/10/news/news_release.2021.06.0506.html

**Government of Newfoundland and Labrador, Environment and Conservation**. Funding Announced for Research to Reuse Ash at Corner Brook Pulp and Paper (News Release). July 7, 2010. https://www.releases.gov.nl.ca/releases/2010/env/0707n07.htm

**Government of Ontario.** Forest biofibre allocation and use. From website https://www.ontario.ca/page/forest-biofibre-allocation-and-use (January, 2023)

**Government of Ontario**. Sustainable forest management: Why it is important. From website https://www.ontario.ca/page/sustainable-forest-management (January, 2023)

**Government of Ontario, Ministry of Agriculture, Food and Rural Affairs (OMAFRA).** Nonagricultural Operations. From website http://omafra.gov.on.ca/english/nm/regs/nmpro/nmpro02-04.htm (January, 2023)

**Government of Ontario, Ministry of Agriculture, Food and Rural Affairs (OMAFRA).** Non-Agricultural Source Materials (NASM). From website http://omafra.gov.on.ca/english/nm/nasm.html (January, 2023)

**Government of Ontario, Ministry of Natural Resources, Crins. W. J, Gray. P.A, Uhlig. P.W.C, Wester. M.C.** The Ecosystems of Ontario, Part 1: Ecozones and Ecoregions. Ontario Ministry of Natural Resources, Peterborough Ontario, Inventory, Monitoring and Assessment, SIB TER IMA TR- 01, 71pp. , 2009

**Government of Ontario, Ministry of Natural Resources and Forestry.** Sustainable Growth: Ontario's Forest Sector Strategy. https://files.ontario.ca/mnrf-fid-forest-sector-strategy-en-2020-08-20.pdf

**Government of Ontario, Ministry of Natural Resources, Forests Division, Forest Management Branch, Forest Policy Section**. Policy Framework for Sustainable Forests. April 6, 1994.

**Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, Ontario.** Forest Biomass Action Plan. March 2022.

**Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, Science Research Branch.** Forest Health Conditions in Ontario, 2020

**Government of Ontario, Ministry of Northern Development, Mines, Natural Resources and Forestry, 2021.** The State of Ontario's Natural Resources - Forests 2021.

**Haliburton Echo**. What is biochar anyway? January 17, 2017, https://haliburtonecho.ca/what-is-biochar-anyway/

**Hall. P.J, Richardson. J.** ENFOR - Energy from the forest. The Forestry Chronicle, September/October 2001, Vol. 77, No. 5

**Hannam. K.D, Deschamps. C, Kwiaton. M, Venier. L, and Hazlett. P.W.** Regulations and guidelines for the use of wood ash as a soil amendment in Canadian forests. Natural Resources Canada, Canadian Forest Service, Great Lakes Forestry Centre. Information Report Number: GLC-X-17, 2016

**Hannam. K.D, Venier. L, Allen. D, Deschamps. C, Hope. E, Jull. M, Kwiaton. M, McKenney. D, Rutherford. P.M, and Hazlett. P.W.** Wood ash as a soil amendment in Canadian forests: what are the barriers to utilization? Canadian Journal of Forest Research. 2018; 48(4): 442-450. https://doi.org/10.1139/cjfr-2017-0351

**Hannam. K.D, Venier. L, Hope. E, McKenney. D, Allen. D, Hazlett. P.W.** AshNet: Facilitating the use of wood ash as a forest soil amendment in Canada. The Forestry Chronicle. 93(01): 17-20. 2017. https://doi.org/10.5558/tfc2017-006

**Hazlett. P, Emilson. C.** Applying wood ash waste to soil: contributing to sustainable forest management in Canada [e-presentation]. March, 2019. http://www.cif-ifc.org/wp-content/uploads/2018/12/Hazlett_Emilson-eLecture-CIF-2019.pdf

**Hazlett. P.** Recycling bioenergy ash in forests: Hiccups and Hurdles. GLFC Webinar Jan 2016. ftp.nrcan.gc.ca/cfs/glfc/2016-01-26-Hazlett_Paul/

**Heart & Soil Ag Products.** Heart & Soil Wood Ash [Commercial Brochure]. 2022. https://www.rmirecycles.com/products-heart-and-soil-wood-ash/

**Hébert. M, Breton. B.** Recyclage agricole des cendres de bois au Québec - État de la situation, impacts et bonnes pratiques agro-environnementales. Agrosolutions, Décembre 2008 VOL. 19 No 2

**Hébert. M.** Guide sur le recyclage des matières résiduelles fertilisantes : Critères de référence et normes réglementaires – Édition 2015. Québec, 2015. ISBN- 978-2-550-72954-9

**Homagain. K, Shahi. C, Luckai. N, Sharma. M.** Biochar-based bioenergy and its environmental impact in Northwestern Ontario Canada: A review. Journal of Forestry Research, 2014.

**Hope. E. S, McKenney. S. W, Allen, D. J, Pedlar. J. H.** A cost analysis of bioenergy-generated ash disposal options in Canada. Canadian Journal of Forest Research, 2016. 47(9): 1222-1231. https://doi.org/10.1139/cjfr-2016-0524

**IEA Bioenergy.** Implementation of bioenergy in Canada – 2021 update. 10-2021. https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Canada_final.pdf

**International Biochar Initiative.** State of the Biochar Industry in 2015: Biochar Companies. https://www.biochar-international.org/wp-content/uploads/2018/04/2015_Company_Database.pdf

**Joseph. R, Diochon. A, Morris. D, Venier. L, Emilson. C**. E, Basiliko. N, Bélanger. N, Jones. T, Markham. J, Rutherford. M. P, Smenderovac. E, Van Rees. K, Hazlett. P. Limited effect of wood ash application on soil quality as indicated by a multisite assessment of soil organic matter attributes. GCB Bioenergy, 14, published by John Wiley & Sons Ltd., 2022. 500–521. https://doi.org/10.1111/gcbb.12928

**Kim. N, Watmough. S, Yan. N.** Wood ash amendments as a potential solution to widespread calcium decline in eastern Canadian forests. Environmental Reviews. 2022; 30(4): 485-500. https://doi.org/10.1139/er-2022-0017

**Knapp. B, and Insam. H**. Recycling of Biomass Ashes: Current Technologies and Future Research Needs. Springer Berlin, Heidelberg, 2011. 10.1007/978-3-642-19354-5_1.

**Koochiching SWCD** [Minnesota, USA], Cooperative Wood Ash Program: Information Program Guide. June 2017. https://koochichingswcd.org/wood-ash/

**Koochiching SWCD** [Minnesota, USA], Cooperative Wood Ash Program: Landowner's Guide for Wood Ash Spreading. June 2017. https://koochichingswcd.org/wood-ash/

**Kopecky. M.J, Meyers. L, Wasko. W.** Using industrial wood ash as a soil amendment. University of Wisconsin-Extension, 1990. http://corn.agronomy.wisc.edu/Management/pdfs/a3635.pdf

**Lama. I (Dr.).** Fact Sheet: Wood Ash as a Soil Amendment. NCASI. From website www.ncasi.org (November 2022)

**Lama. I, Sain. D.** A case study review of wood ash land application programs in North America. TAPPI Journal, February 2021. https://imisrise.tappi.org/TAPPI/Products/21/FEB/21FEB111.aspx

**Lamers. F (DNVGL), Cremers. M (DNVGL), Matschegg. D** (Bioenergy2020+), Schmidl. C (Bioenergy2020+), Hannam. K (CFS - Natural Resources Canada), Hazlett. P (CFS - Natural Resources Canada), Madrali. S (CANMET – Natural Resources Canada), Primdal Dam. B (Emineral A/S), Roberto. R (ENEA), Mager. R (Ontario Power Generation), Davidsson. K (SP Technical Research Institute of Sweden), Bech. N (StandardConsult ApS), Feuerborn. HJ (VGB), Saraber. A (Vliegasunie). Options for increased use of ash from biomass combustion and co-firing (2018) IEA Bioenergy: Task 32: Biomass Combustion and Cofiring. 2018

**Lattimore. B, Smith. T, Richardson. J.** Coping with complexity: Designing low-impact forest bioenergy systems using an adaptive forest management framework and other sustainable forest management tools. 2010. The Forestry Chronicle. 86(1): 20-27. https://doi.org/10.5558/tfc86020-1

**Lehmann. H (Dr).** How natural cycles can be closed with wood ash. Bioeconomy BW-BIOPRO Baden-Württemberg GmbH. 10-Jul-2020. https://www.biooekonomie-bw.de/en/articles/news/how-natural-cycles-can-be-closed-wood-ash

**Levin. R, Eriksson. H.** Good-practice guidelines for whole-tree harvesting in Sweden: Moving science into policy. The Forestry Chronicle_January/February 2010, VOL. 86, NO. 1

**Marsh. J. H, Dale. C.** Muskoka. The Canadian Encyclopedia. 05 November 2018, Historica Canada. From website www.thecanadianencyclopedia.ca/en/article/muskoka-lakes.

**Massachusetts Division of Energy Resources, Biomass Energy Centre.** Wood Pellet Heating [Guidebook]: A Reference on Wood Pellet Fuels & Technology for Small Commercial & Institutional Systems. June, 2007

**McElligott. K, Page-Dumroese. D, Coleman. M.** Bioenergy Production Systems and Biochar Application in Forests: Potential for Renewable Energy, Soil Enhancement, and Carbon Sequestration (Research Note). United States Department of Agriculture, Forest Service, Rocky Mountain Research Station, October 2011.

**Morris.D.M, Fleming. R.L, Hazlett.P.W,** Ontario, Canada's LTSP Experience: Forging Lasting Research Partnerships and the Adaptive Management Cycle in Action. Journal of Forestry, Volume 118, Issue 3, May 2020, Pages 337–351, https://doi.org/10.1093/jofore/fvaa002

**National Geographic**. Biomass Energy. From website: https://education.nationalgeographic.org/resource/biomass-energy (January, 2023)

**Natural Resources Canada**. AshNet: Why study wood ash?. From website https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/great-lakes-forestry-centre/ashnet/20279 (January, 2023)

**Natural Resources Canada**. Bioenergy from biomass. From website https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-bioeconomy-bioenergy-bioproducts/bioenergy-biomass/13323 (January, 2023)

**Natural Resources Canada**. Forest bioeconomy, bioenergy and bioproducts. From website https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-bioeconomy-bioenergy-bioproducts/13315 (January, 2023

**Natural Resources Canada**. Solid Biofuels Bulletin No1: Solid Biomass Fuels. M153-1/1E-PDF, January, 2017. 978-0-660-05074-4. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/NRCAN_BB_no1_e_accessible.pdf

**Natural Resources Canada**. Sustainable Forest Management: Forest management planning. From website https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/forest-management-planning/17493 (January, 2023)

**Natural Resources Canada**. Canada's commitment to sustainable forest management. From website https://www.nrcan.gc.ca/our-natural-resources/forests/sustainable-forest-management/sustainable-forest-management-canada/24361 (January, 2023)

**Natural Resources Canada**. The State of Canada's Forests Annual Report 2021. https://www.nrcan.gc.ca/sites/nrcan/files/forest/sof2021/6317_NRCan_SoF_AR_2021_EN_P7B_web_accessible.pdf

**Natural Resources Canada, Canadian Forest Service.** Is forest bioenergy good for the environment? Science-Policy Notes. December 2010. https://cfs.nrcan.gc.ca/publications?id=31936

**Natural Resources Canada, Great Lakes Forestry Centre.** Canadian Wood Ash Chemistry Database. 2022. https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/great-lakes-forestry-centre/ashnet/canadian-wood-ash-chemistry-database/20288

**Natural Resources Canada. Great Lakes Forestry Center**, e-bulletin Issue 14, Summer 2011: Bioeconomy in forest sector revitalization. https://d1ied5g1xfgpx8.cloudfront.net/pdfs/33032.pdf

**Natural Resources Canada. Great Lakes Forestry Centre**, e-Bulletin, Issue 12, Winter 2011: New biomass harvesting study examines sustainability, biodiversity, and the bioeconomy. https://cfs.nrcan.gc.ca/series/read/94

**Nazaroff. D.** Biochar: The waste product that could help mitigate climate change. University of New South Wales. From website https://phys.org/news/2021-08-biochar-product-mitigateclimate.html (January, 2023)

**NCASI.** About NCASI. From website https://www.ncasi.org/about-ncasi/ (January, 2023)

**NEBRA (North East Biosolids & Residuals Association).** From Liability to Asset, a residual success story by J.D. Irving. 2014 https://www.nebiosolids.org/successful-programs?rq=ash

**New Hampshire Department of Environmental Services.** Certified Waste-Derived Product No. 15, International Paper Wood/Paper Mill Sludge Ash Material, December 12, 2003. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/CWDP-15.pdf

**New Hampshire Department of Environmental Services.** Certified Waste-Derived Product No. 8 - Revised Wood Ash Used as an Ingredient in Agricultural Liming Materials, May 20, 1999. https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/CWDP-08.pdf

**New Hampshire Department of Environmental Services**. Certified Waste-Derived Products. From website https://www.des.nh.gov/waste/solid-waste/waste-reduction-and-diversion/certified-waste-derived-products (January, 2023)

**New Hampshire Department of Environmental Services**. New Hampshire Code of Administrative Rules: CHAPTER Env-Sw 1700 Requirements for Land Application of Wood Ash. From website https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/2020-01/Env-Sw%201700.pdf (January, 2023)

**Nishio. G, Ersson. T**. Ash and Biosolids Spreading Trial, June 2016 – Technical Report No. 28. FPInnovations, 2016.

**Nishio. G, Ersson. T**. Spreading Wood Ash on Forest Land in Canada: An Introduction. FPInnovations, 2016.

**O'Neill. K.** Nutrient Management in Forest Management Planning, PhD. Diss., Trent University (Canada), 2022.

**Okmanis. M, Petaja. G, Lupikis. A.** Productivity of mechanized wood ash application in forest. Research for Rural Development. 2017. 1. 62-68. 10.22616/rrd.23.2017.009.

**Ontario Power Corporation (OPG)**. Biomass Power. From website https://www.opg.com/powering-ontario/our-generation/biomass/ (January, 2023)

**Ouellet. J.** Domtar Windsor closes the loop on circular economy. August 7, 2018. https://www.paperadvance.com/blogs/jaclin-ouellet/domtar-windsor-closes-the-loop-on-circular-economy.html

**Pedersen. S, Gangaas. K. E, Chetri. M, Andreassen. H.P.** Economic Gain vs. Ecological Pain—Environmental Sustainability in Economies Based on Renewable Biological Resources. Sustainability 2020, 12(9), 3557; https://doi.org/10.3390/su12093557

**Pembina Institute.** Biomass Sustainability Analysis: Summary Report 2011. Ontario Power Generation, 2011. https://www.opg.com/document/biomass-sustainability-analysis-report-pdf/

**Pettersson. M, Björnsson.l, Börjesson. P.** Recycling of ash from co-incineration of waste wood and forest fuels: An overlooked challenge in a circular bioenergy system. Biomass and Bioenergy v142 (November 2020)

**Pitman. R.M.** Wood ash use in forestry – a review of the environmental impacts. Oxford University Press on behalf of Institute of Chartered Foresters, 2006 and Forestry, Vol. 79, No. 5, 2006. doi:10.1093/forestry/cpl041

**Puddister. D, Dominy. S.W.J, Baker. J.A., Morris. D.M, Maure. J, Rice. J.A, Jones. T.A, Majumdar. I, Hazlett. P.W, Titus. B.D, Fleming. R.L,Wetzel. S**. Opportunities and challenges for Ontario's forest bioeconomy. The Forestry Chronicle July/August 2011, Vol. 87, No 4

**Pugliese. S, Jones. T, Preston. M. D, Hazlett. P, Tran. H, Basiliko. N.** Wood ash as a forest soil amendment: The role of boiler and soil type on soil property response. Canadian Journal of Soil Science. 94(5): 621-634. 2014. https://doi.org/10.4141/cjss-2014-037

**Pulp & Paper Canada.** 2021 Pulp, Paper, and Bioeconomy Map. From website https://www.pulpandpapercanada.com/wp-content/uploads/2021/06/PPC-MILL-MAP-2021.pdf

**ReEnergy**. Stratton Provides Ash to Farmers. From website https://reenergyops.com/stratton-ash-outlets/ (January, 2023)

**Resolute Forest Products**. From Forest to Farm: Resolute Reduces Waste through Land Spreading. 2021. From website https://blog.resolutefp.com/2021

**Resolute Forest Products.** Minimizing waste and maximizing the value of resources: Resolute's 2020 Highlights. From website https://blog.resolutefp.com

**Roach. J, Berch. S.M**. A compilation of forest biomass harvesting and related policy in Canada. Prov. B.C., Victoria, B.C. Tech. Rep. 081. 2014 www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr081.htm

**Romppanen. J.** Biomass ash fertilisation sustains bio energy cycle. VGB PowerTech 4:2016. https://cdn2.hubspot.net/hubfs/2200893/Granulators/Offers/VGB%20PowerTech%202016-04%20(062-066)%20ROMPPANEN%20Autorenexemplar.pdf

**Royal Swedish Academy of Agriculture and Forestry**. Forests and Forestry in Sweden. 2015. https://www.skogsstyrelsen.se/globalassets/in-english/forests-and-forestry-in-sweden_2015.pdf

**Rutherford. P.M, Massicotte. H.B, Chisholm. C.E, Jull. M. J**. Land Application of Bioenergy Ashes at the Aleza Lake Research Forest. BC Forest Professional, March-April 2016.

**Ryan. M.** An evaluation of spreading mill biosolids in a forestry operation. FPInnovations, October 2000. https://library.fpinnovations.ca/en/permalink/fpipub40473

**Saunders. O.** Guide to Using Wood Ash as an Agricultural Soil Amendment. University of New Hampshire Cooperative Extension, 2018. https://extension.unh.edu/sites/default/files/migrated_unmanaged_files/Resource004042_Rep5718.pdf

**Scheepers. G. P, du Toit. B.** Potential use of wood ash in South African forestry: a review. Southern Forests: a Journal of Forest Science (2016), 78:4, 255-266, DOI: 10.2989/20702620.2016.1230716

**Stupak. I, Asikainen. A, Röser. D, Pasanen. K.** Review of Recommendations for Forest Energy Harvesting and Wood Ash Recycling from *Sustainable Use of Forest Biomass for Energy (Röser. D, Asikainen. A, Raulund-Rasmussen. K, Stupak. I)*. Springer, 2008.

**Swedish Forest Agency (Skogsstyrelsen).** Regular Recycling of Wood Ash to Prevent Waste Production (RecAsh): Technical Final Report. 2007. EU Life Programme: Project Number LIFE03 ENV/S/000589

**Swedish Forest Agency (Skogsstyrelsen).** Regular Recycling of Wood Ash to Prevent Waste Production: RecAsh - A Life-environment demonstration project (Layman's Report). [Year of publication estimated at 2006].

**Swedish Forest Agency (Skogsstyrelsen).** Sustainable forest management in Sweden. 2011

**Tampier. M, Smith. D, Bibeau. E, Beauchemin. P.A, (Envirochem Services, Inc.)** Identifying Environmentally Preferable Uses For Biomass Resources Stage 1 Report: Identification of Feedstock -to-Product Threads. Natural Resources Canada, Commission for Environmental Co-operation, National Research Council of Canada, 2004

**Taylor. L.L, Driscoll. C.T, Groffman. P.M, Rau. G.H, Blum. J.D and Beerling. D.J**. Increased carbon capture by a silicate-treated forested watershed affected by acid deposition. 2021. Biogeochem. 18: 169-188

**Tecwill Granulators Oy.** Bio Fly Ash Is Too Valuable to Waste [commercial brochure]. 2022. https://www.tecwillgranulators.com/en/brochures

**The Conference Board of Canada.** Use of Forest Resources. From website https://www.conferenceboard.ca/hcp/provincial/environment/forest-resources.aspx (January, 2023)

**Tkacz. B, Moody. B, Villa Castillo. J, Fenn. M.E.** Forest health conditions in North America. Environmental Pollution 155 (2008) 409e425. doi:10.1016/j.envpol.2008.03.003

**United Nations: Climate Action.** What is renewable energy? From website https://www.un.org/en/climatechange/what-is-renewable-energy? (January, 2023)

**University of Georgia Cooperative Extension.** Best Management Practices for Wood Ash as Agricultural Soil Amendment. 2013. https://extension.uga.edu/publications/detail.html?number=B1142&title=Best%20Management%20Practices%20for%20Wood%20Ash%20as%20Agricultural%20Soil%20Amendment

**University of Maine Cooperative Extension.** Using Wood Ash on Your Farm. 2006. https://extension.umaine.edu/publications/2279e/

**University of Northern British Columbia**. UNBC Research: Waste from Cities and Bioenergy Plants could be the Fertilizer of the Future. August 23, 2013, https://www2.unbc.ca/releases/9796/unbc-research-waste-cities-and-bioenergy-plants-could-be-fertilizer-future

**USDA National Institute of Food and Agriculture (NIFA).** Cooperative Extension System. From website https://www.nifa.usda.gov/about-nifa/how-we-work/extension/cooperative-extension-system (January, 2023)

**van Eijk. R.J Obernberger. I, Supancic. K. [KEMA/BIOS]** Options for increased utilization of ash from biomass combustion and co-firing (IEA Bioenergy Tast 32 Deliverable D4). KEMA IEA Bioenergy Task 32: Biomass combustion and co-firing. 2012

**Vance. E.** Land Application of Wood-Fired and Combination Boiler Ashes: An Overview. Journal of Environmental Quality.1996. 25. 10.2134/jeq1996.00472425002500050002x.

**Vance. E.** Recycling Paper Mill By-products on Forest Lands: By-product Composition, Potential Applications, and Industry Case Studies. NCASI, January 2000. product_Composition_Potential_Applications_and_Industry_Case_Studies

**Varnagirytė-Kabašinskienė. I**. Toward the rational use of forest biomass: Lithuanian case study. J. For. Sci. 2012, 58(10):465-471 | DOI: 10.17221/10/2012-JFS

**Voegele. E.** Canadian wood pellet production to reach 3.8M metric tons in 2021. Biomass Magazine, July 13, 2021

**Voegele. E.** USDA to invest $1B in Partnerships for Clmate-Smart Commodities. Biomass Magazine, February 14, 2022. https://biomassmagazine.com/articles/18718/usda-to-invest-1b-in-partnerships-for-climate-smart-commodities

**World Resources Institute.** Ontario, Canada: Reorienting Local Economies by Converting the Atikokan and Thunder Bay Coal-Fired Generating Stations. From website https://www.wri.org/update/ontario-canada-reorienting-local-economies-converting-atikokan-and-thunder-bay-coal-fired (January, 2023)

# Glossary and Acronyms

***Acid Deposition***

Acid deposition is a more formal term for 'acid rain.' For causes and effects of acid rain, see: https://www.canada.ca/en/environment-climate-change/services/air-pollution/issues/acid-rain-causes-effects.html

***ACM - Amendements calciques ou magnésiens, or calcium or magnesium amendments (Québec)***

ACM is a classification of fertilizer as defined by the **BNQ** (Bureau de normalization du Québec). It falls under the 'liming materials from industrial processes' category, which includes 'calcium or magnesium amendments' (ACMs) such as wood ash.

For more information see Bureau de normalisation due Quebec, 2022 - Norme BNQ 0419-090 Amendements minéraux – Amendements calciques ou magnésiens provenant de procédés industriels https://www.bnq.qc.ca/fr/normalisation/environnement/amendements-calciques-ou-magnesiens.html

***Base Cations (BC)***

A base cation is a term used in chemistry and refers to a positively charged ion from group 1 or 2 of the periodic table. Group 1 and 2 of the periodic table encompass the alkali metals or alkaline earth metals. A common characteristic of them is that they are neutral or non-acidic, i.e., 'base.'

Base cations in soil affect its pH, or acidity. Certain cations such as potassium, calcium, and magnesium are essential nutrients for forest ecosystems and vegetation, and are thus of importance for the sustainability of those ecosystems.

In most soils across eastern Canada, calcium is the dominant base cation accounting for between 50% and 70% of the exchangeable base cation pool. Reference: Kim. N, Watmough. S, Yan. N, 2022, **(**referencing Watmough et al. 2005).

***Biochar***

Biochar is the by-product of organic material that is combusted in the absence of oxygen; this process is called pyrolysis. While normal combustion consumes most of the organic carbon in the material that is burned, pyrolysis leaves much of the carbon in the biochar product. Biochar is a fairly nascent bioeconomic industry and contributes to the circular economy.

***Bioeconomy***

According to the Canadian Council of Forest Ministers (**CCFM**): **"**The forest bioeconomy refers to economic activity generated by converting sustainably managed renewable forest-based resources, primarily woody biomass and nontimber forest products, into value-added products and services using novel and repurposed processes. Although there is no single, accepted definition of the bioeconomy, it is generally recognized that the key attribute of a healthy bioeconomy is the knowledge-based, competitive, and innovative production and sustainable use of biological resources, processes, and principles to provide eco-friendly goods and services." Reference: Canadian Council of Forest Ministers (CCFM). A Forest Bioeconomy Framework for Canada. 2017.

### *Bioenergy*

Bioenergy is energy produced from renewable, biological sources such as **biomass**. Biomass is plant material that can be turned into fuel (also known as **biofuel** when it is made from biological material) to supply heat and electricity. Bioenergy can be obtained from many forms of biofuels. These include liquid biofuels used to run motor vehicles, and forest wood residue used to run pulp mill and other industrial operations.

Reference: Natural Resources Canada. *Bioenergy from biomass*. From website https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-bioeconomy-bioenergy-bioproducts/bioenergy-biomass/13323 (January, 2023)

### *Biofuel*

See **Bioenergy**.

### *Biomass*

Biomass is a term for the biological material that comes from living or recently living plants, including trees – from their roots, trunks and branches to their bark, needles, leaves and fruit. This may include organic materials of biological origin sourced from forestry, agriculture, and aquaculture.

Biomass is typically understood to include:

- unused **forest harvest residues**
- wood salvaged after insect outbreaks, wildfires, disease, or other natural disturbance
- unused and untreated wood fibre residues from sawmills or lumber mills
- other plant-based sources such as straw, or compost

In addition to forest material, biomass can include agricultural waste (unused crops), and municipal waste such as compost.

Materials in the first three categories above are sometimes referred to as **woody biomass.** See also **forest biofibre.**

Referencing: Natural Resources Canada, from website https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-bioeconomy-bioenergy-bioproducts/13315 (January, 2023)

### *BNQ - Bureau de normalization du Québec*

The BNQ is mandated by the government of Quebec to lead standardization activities in that province. The organization is recognized by the Standards Council of Canada. Among other things, the BNQ has developed commercial standards and a certification regime for fertilizers. This includes ‘liming materials from industrial processes’, which includes 'calcium or magnesium amendments' (ACMs). Wood ash falls under this category.

For more information see https://www.bnq.qc.ca/en/the-bnq-in-brief.html

### *Bottom Ash*

The elemental composition of ash is influenced by the part of the boiler system it is retrieved from. Typically, particulates that become airborne and escape up the chimney - or stack - during the combustion process is captured by filters and is referred to as **fly ash** (sometimes referred to as cyclone ash). Ash removed from the main boiler apparatus is referred to as **bottom ash**.

### *BUC - Biosolids Utilization Committee (Ontario)*

The classification and safe usage of **NASM** in Ontario is evaluated by the Biosolids Utilization Committee (BUC). The BUC is a multi-stakeholder, inter-ministerial committee that advises and makes recommendations to the **MECP** and **OMAFRA** on matters related to the use of biosolids and other materials (NASM) on agricultural land.

Referencing OMAFRA, 'Non-agricultural Operations,' from website http://omafra.gov.on.ca/english/nm/regs/nmpro/nmpro02-04.htm (January 2023)

### *CCFM – Canadian Council of Forest Ministers*

'Established in 1985, the Canadian Council of Forest Ministers (CCFM or Council) provides an important forum for federal, provincial and territorial governments to come together to discuss and exchange information, provide leadership and promote action on common forest and forestry-related issues of Canadian public and international concern.

'The CCFM membership is composed of fourteen federal, provincial, and territorial ministers. The secretariat for the Council is provided by **Natural Resources Canada**'s **Canadian Forest Service**.'

From website: https://www.ccfm.org/about/ (February, 2023)

### *CFIA - Canadian Food Inspection Agency*

The CFIA is a science-based regulator in Canada. It has a broad mandate that encompasses food safety, animal health, plant health and international market access.

See https://inspection.canada.ca/

### *CFS - Canadian Forest Service*

The Canadian Forest Service is the national and international voice for Canada's forest sector. The CFS is part of **Natural Resources Canada**, a federal government department, and have an office in Ottawa as well as 6 research centres across the country. The CFS collaborate closely with Canada's provinces and territories to ensure Canadian forests are sustainable and healthy for the people of Canada and the world to enjoy.

See https://www.nrcan.gc.ca/our-natural-resources/forests-forestry/the-canadian-forest-service/about-canadian-forest-service/17545

### *CFSA - Crown Forest Sustainability Act (Ontario)*

The CFSA is a legislative act in the province of Ontario, Canada. The CFSA codifies the governing principles by which Crown forest is managed in Ontario.

As stated in the Act, the purpose of the Act is "*to provide for the sustainability of Crown forests and, in accordance with that objective, to manage Crown forests to meet social, economic and environmental needs of present and future generations*."

https://www.ontario.ca/laws/statute/94c25

### *CM1, CM2 - Content of regulated metal (Ontario)*

CM refers to 'content of regulated metal' in trace element thresholds pertaining to **NASM** as defined by the province of Ontario.

In Ontario, there are two trace element thresholds that wood ash (or **NASM**) is evaluated against: CM1, and CM2. The concentration of 11 trace elements (arsenic, cadmium, cobalt, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc) are evaluated against both thresholds. If the concentration of all metals fall *below* CM1 levels, then the material may be considered for use as a soil amendment. If concentration levels of any of the metals fall *between* CM1 and CM2, then the use of the material as a soil amendment is dependent upon the concentration of metal levels in the soil at the intended addition site. It is also dependent upon other considerations such as minimum depth of soil to groundwater, and proximity to surface water. If any metal concentration levels *exceed* CM2 thresholds, then the substance is considered to be a hazardous waste and cannot be applied to the land. Note: trace metal limits are not exclusive of other potential regulatory limitations.

### *Co-firing*

Co-firing is the burning of two (or more) different types of materials at the same time. Within the context of biomass and biomass ash, co-firing is typically understood to be the use of biomass as a fuel source *in addition to* other traditional fossil fuel sources such as coal and natural gas in the same power plant.

See https://www.etipbioenergy.eu/value-chains/conversion-technologies/conventional-technologies/biomass-co-firing

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2013/IRENA-ETSAP-Tech-Brief-E21-Biomass-Co-firing.pdf

### *Cogeneration*

Cogeneration refers to the use of biomass-derived energy for more than one purpose. A common example is in pulp and paper mills where boilers using biomass fuel produce a high pressure steam. The pulping and papermaking processes require this steam to be at a much lower pressure in a near saturated state. Reducing the high pressure boiler steam to lower levels can be done through a turbine/generator. Thus the original fuel "co-generates" both electricity and process steam.

Reference: Tampier. M, Smith. D, Bibeau. E, Beauchemin. P.A, (Envirochem Services, Inc.) Identifying Environmentally Preferable Uses For Biomass Resources Stage 1 Report: Identification of Feedstock -to-product Threads. Natural Resources Canada, Commission for Environmental Co-operation, National Research Council of Canada, 2004

### *Combined Heat and Power (CHP)*

Combined Heat and Power (CHP) is a specific implementation of cogeneration. It is effectively the production of electricity and heat from a single fuel source.

### *Cooperative Extension System (United States)*

The Cooperative Extension System is a program in the United States affiliated with the United States National Institute of Food and Agriculture. It encourages the nation's academic institutions to provide outreach to local communities and 'bring vital, practical information to agricultural producers, small business owners, consumers, families, and young people.'

The intent of the program is to translate research into education and action. The Cooperative Extension Service has a presence in every county across the United States, and brings cutting-edge discoveries from research laboratories to individuals, communities, and businesses who can put knowledge into practice to improve their lives.

See https://www.nifa.usda.gov/about-nifa/how-we-work/extension/cooperative-extension-system

https://northeastextension.org/about-cooperative-extension/

### *DH - District Heating*

District heating refers to energy provided to multiple buildings from a central energy plant or plants. Steam or hot water produced at the plant is transmitted 24/7 through highly insulated underground thermal piping networks. The thermal energy is transferred to the building's heating system, avoiding the need for boilers in individual buildings. Reference: From website https://www.districtenergy.org/topics/district-heating (January 2023)

In Canada, a number of communities have operated district energy systems for many decades. The oldest system is in London, Ontario dating back to 1880. In Ontario, district energy systems are currently operating in Toronto, Ottawa, London, Markham, Hamilton, Sudbury, Cornwall, and Windsor.

Reference from website https://www.markhamdistrictenergy.com/district-energy-101/#:~:text=In%20Canada%2C%20a%20number%20of,Sudbury%2C%20Cornwall%2C%20and%20Windsor.

### *ECA - Environmental Compliance Approval (Ontario)*

An environmental compliance approval is a permit from the government that sets out the parameters by which a regulated activity must adhere in order to protect the natural environment and thereby uphold the Environmental Protection Act. For more information see https://www.ontario.ca/page/environmental-compliance-approval

### *Feedstock*

Feedstock refers to the raw materials that are input or fed into a process for conversion into something different. In the context of the **bioeconomy**, a feedstock is defined as any renewable, biological material that can be used directly as a fuel, or converted to another form of fuel or energy product.

### *Fly Ash (also referred to as Cyclone Ash)*

The elemental composition of wood ash is influenced by the part of the boiler system it is retrieved from. Typically, particulates that become airborne and escape up the chimney - or stack - during the combustion process are captured by filters and referred to as **fly ash** (sometimes referred to as cyclone ash). Ash removed from the main boiler apparatus is referred to as **bottom ash**.

### *Forest Biofibre*

As defined by the government of Ontario, forest biofibre includes: unused **forest harvest residues,** as well as wood salvaged after insect outbreaks, wildfires, disease, or other natural disturbances.

Puddister et al (referencing Ontario's *Forest Biofibre – Allocation and Use* directive), note that the definition of forest biofibre includes tree tops, cull trees or portions thereof, individual and stands of unmerchantable and unmarketable trees, and trees salvaged following natural disturbances. The differentiation between forest biofibre and forest biomass is the latter includes additional organic material such as roots and stumps. As pointed on the Ontario.ca website, forest biofibre does not include residual by-products such as wood shavings, sawdust, bark or wood chips produced during mill operations.

References: Government of Ontario, 2023 - Forest biofibre allocation and use; and Puddister. D, Dominy. S.W.J, Baker. J.A., Morris. D.M, Maure. J, Rice. J.A, Jones. T.A, Majumdar. I, Hazlett. P.W, Titus. B.D, Fleming. R.L,Wetzel. S. Opportunities and challenges for Ontario's forest bioeconomy. The Forestry Chronicle July/August 2011, Vol. 87, No 4

### *Forest Harvest Residues (also referred to as Logging Residue, or Slash)*

Forest harvest residue refers to the wood left in the forest after forestry logging operations. These residues generally include woody debris from final felling such as branches, leaves, stumps, roots, tops, bark, as well as small trees from thinning and clearing operations. It may also include un-merchantable stem wood.

These tree components were traditionally left behind to decompose in the forest, however, they have been increasingly removed from the forest in recent decades for use in other wood fibre products and/or as fuel for biomass energy.

### *Forwarder*

A 'forwarder' in forestry is a large tractor with an articulated log bunk or cargo compartment. Forwarders often have a boom mounted grapple for loading and unloading material. The operator's cab may be fixed or capable of rotating on the chassis.

Forwarders currently exist having up to eight wheels. Traction and flotation can be increased by adding tracks that slide on over the dual wheels or by opting for wider tires. Tire chains may also be applied for additional traction in snow or mud. For more information see: https://www.fs.usda.gov/forestmanagement/equipment-catalog/forwarders.shtml

### *FOTMW - Friends of the Muskoka Watershed*

The Friends of the Muskoka Watershed (FOTMW) is a non-profit, charitable organization located out of Bracebridge, Ontario. A precis of their approved statement of purpose is:

> *"To protect freshwater watersheds using projects that: preserve, protect and restore them, improve management to adapt to major stressors, increase public understanding of their importance, and advance education through research and communicating results."*

The FOTMW and their academic partners are studying the impact of historic acid rain on forests and watersheds in the Muskoka and Central Ontario region. For more information see https://fotmw.org/

### *FPAC - Forest Products Association of Canada*

According to the FPAC website: 'FPAC provides a voice for Canada's wood, pulp, and paper producers nationally and internationally in government, trade, and environmental affairs. As an industry with annual revenues exceeding $75B, Canada's forest products sector is one of the country's largest employers operating in over 600 communities, providing 225,000 direct jobs, and over 600,000 indirect jobs across the country.' See https://www.fpac.ca/

### *FPInnovations*

FPInnovations is a private, not-for-profit organization that specializes in the creation of solutions in support of the Canadian forest sector's global competitiveness.

FPInnovations was created from a merger of three leading Canadian research institutions that included: Paprican (Pulp and Paper Research Institute of Canada), FERIC (Forest Engineering Research Institute of Canada), and Forintek (Canada's wood products research institute). "*It is now the largest public-private forest research organization in the world.*" Its membership represents approximately 50% of the forest sector's contribution to Canada's GDP.

Reference: Canadian Council of Forest Ministers, 2015 - Forest Sector Innovation In Canada (2015): White Paper: Opportunities for the Canadian Council of Forest Ministers.
See https://www.fpinnovations.ca/

### *Full-tree Harvesting (FTH) (also referred to as Whole-tree Harvesting (WTH))*

Full-tree harvesting is a term used in forestry when the entire aboveground portion of trees (stem wood, tops, branches) are moved or 'forwarded' to roadside for processing during forest harvesting.

### *Great Lakes Forestry Centre (GLFC)*

The Great Lakes Forestry Centre is one of six **CFS** research facilities across Canada. It is located in Sault Ste. Marie, Ontario. Among its research priorities, the GLFC focuses on 'Generating

knowledge of the impacts of human-induced disturbances on forest ecosystems, and informing the development of ecosystem-based forest management policy to sustain ecological integrity. Work includes examining the ecological impacts and economic analysis of biomass harvesting on site productivity, soil nutrients and biodiversity.' Reference: Natural Resources Canada from website: https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/forestry-research-centres/great-lakes-forestry-centre/13459 (January 2023)

### *IEA Bioenergy*

"IEA Bioenergy is a Technology Collaboration Programme (TCP) set up in 1978 by the International Energy Agency (IEA) with the aim of improving cooperation and information exchange between countries that have national programmes in bioenergy research, development and deployment. Technology Collaboration Programmes are independent bodies operating in a framework provided by the IEA. There are 42 currently active Technology Collaboration Programmes, one of which is IEA Bioenergy."

Canada is one of 17 countries that participate in the research activities of International Energy Agency (IEA) Bioenergy.

Reference: https://www.ieabioenergy.com/about/ ; and Natural Resources Canada from website: https://www.nrcan.gc.ca/our-natural-resources/forests/industry-and-trade/forest-bioeconomy-bioenergy-bioproducts/bioenergy-biomass/13323

### *Liming*

**Liming** refers to the application of calcium (Ca) and magnesium (Mg) rich materials in various forms such as limestone, wood ash, marl, and chalk. In acidic soils, these liming materials react as a base and neutralize soil acidity.

### *Logging Residue*

See **Forest Harvest Residues**.

### *Long-term Soil Productivity Network (LTSP) (Ontario)*

As an outcome of a Forest Class Environmental Assessment (EA) for timber management on Crown Lands that was conducted just prior to the introduction of the **CFSA**, the Ontario Ministry of Natural Resources was mandated to establish long-term research trials to evaluate the effects of full-tree harvesting on long-term soil productivity.

At some point during the evolution of the Ontario LTSP (long-term soil productivity) project, the study of the effects of wood ash application on full-tree harvested sites was incorporated into site experiments. For more information see:

**North America (U.S.): https://www.fs.usda.gov/rmrs/ltsp-network**

**British Columbia: https://www.sgrc.selkirk.ca/projects/long-term-soil-productivity/**

**Ontario: https://academic.oup.com/jof/article/118/3/337/5734758**

Referencing Morris.D.M, Fleming. R.L, Hazlett.P.W, Ontario, Canada's LTSP Experience: Forging Lasting Research Partnerships and the Adaptive Management Cycle in Action. Journal of Forestry, Volume 118, Issue 3, May 2020, Pages 337–351, https://doi.org/10.1093/jofore/fvaa002

### *MECP - Ministry of Environment, Conservation and Parks (Ontario)*

Ontario's Ministry of the Environment, Conservation and Parks (MECP) is responsible for monitoring and protecting the province's air, land and water. It protects species at risk and their habitat, as well as addressing climate change. In addition, the MECP helps communities prepare for the impacts of climate change as well as reduce litter and waste. The MECP mandate includes managing Ontario's parks and conservation reserves now and for future generations of Ontarians.

The MECP is committed to implementing the most effective and affordable evidence-based solutions to protect the environment, reduce greenhouse gas emissions, and build resilience to the impacts of a changing climate.

From website: https://www.ontario.ca/page/published-plans-and-annual-reports-2021-2022-ministry-environment-conservation-and-parks#:~:text=Ontario's%20Ministry%20of%20the%20Environment,and%20managing%20Ontario's%20parks%20and (January, 2023)

### *MRF - Matières résiduelles fertilisantes (Québec)*

The english translation for matières résiduelles fertilisantes is 'fertilizing residual material.' MRF's are: 'residual materials whose use is intended to maintain or improve, separately or simultaneously, plant nutrition, as well as the physical and chemical properties and biological activity of soils'. Reference: Hébert. M. Guide sur le recyclage des matières résiduelles fertilisantes : Critères de référence et normes réglementaires – Édition 2015. Québec, 2015. ISBN- 978-2-550-72954-9

### *Natural Resources Canada (NRCan)*

Natural Resources Canada develops policies and programs that enhance the contribution of the natural resources sector to the economy, improve the quality of life for all Canadians, and conducts innovative science in facilities across Canada to generate ideas and transfer technologies.

NRCan is an established leader in the fields of:

- energy sources and distribution
- forests and forestry
- minerals and mining
- earth sciences
- energy efficiency
- science and data

NRCan represents Canada at the international level to meet the country's global commitments related to the sustainable development of natural resources.

From website: https://www.nrcan.gc.ca/home/about-us/10838 (January, 2023)

### *NCASI (National Council for Air and Stream Improvement)*

The National Council for Air and Stream Improvement, Inc. is an association organized to serve the forest products industry as a center of excellence providing unbiased, scientific research and technical information necessary to achieve the industry's environmental and sustainability goals. NCASI's mission is to help its members cost-effectively meet their environmental and sustainability goals through basic and applied research, technical support, and education. NCASI draws members from the United States, Canada, and beyond.

NCASI research is conducted throughout the United States and Canada. The organization has two regional centers, an aquatic biology facility, a Canadian office, and numerous forestry-related field study sites. Their corporate headquarters is located in Cary, North Carolina.

From website: https://www.ncasi.org/about-ncasi/ (January, 2023)

### *NASM (Non-agricultural Source Material (Ontario))*

Non-agricultural source material, or NASM, is a regulatory term used in Ontario. It is 'treated and recycled material from non-agricultural sources such as like leaf and yard waste, fruit and vegetable peels, food processing waste, pulp and paper biosolids and sewage biosolids, that is applied to agricultural land to provide a beneficial use.' For more information see: http://omafra.gov.on.ca/english/nm/nasm.html#:~:text=Non%2DAgricultural%20Source%20Material%2C%20or,to%20provide%20a%20beneficial%20use.

### *OMAFRA - Ontario Ministry of Agriculture, Food and Rural Affairs*

OMAFRA supports the growth of Ontario's agri-food sector by providing business support to farmers, and investing in research and innovation. OMAFRA enforces and improves food safety, as well as engages in initiatives that expand agriculture in the North, and strengthens Ontario's rural communities.

From website: https://www.ontario.ca/page/ministry-agriculture-food-and-rural-affairs#:~:text=Growing%20Ontario's%20agri%2Dfood%20sector,stronger%20economy%20for%20the%20province.

### *OPG - Ontario Power Generation*

OPG oversees power generation in Ontario. The company's power portfolio in Ontario includes 66 hydroelectric stations, 2 nuclear stations, 1 biomass station (Atikokan), 1 solar facility, 1 dual-fuelled (oil and gas) station, and 4 Atura power stations (combined cycle gas and turbine). OPG also owns two other nuclear generating stations in Ontario that are leased to Bruce Power L.P.

From website: https://www.opg.com/about-us/ (January, 2023)

### *Silviculture*

Similar to the concept of horticulture in relation to gardening, silviculture is the growth and management of trees. Natural Resources Canada describes silviculture as being 'The theory and practice of controlling the establishment, composition, growth, and quality of forest stands to achieve the objectives of management.' From website: https://cfs.nrcan.gc.ca/terms/read/1056

### *Slash*

See **Forest Harvest Residues**.

### *Whole-tree Harvesting (WTH) (also referred to as Full-tree Harvesting)*

Whole-tree harvesting is a term used in forestry when the entire aboveground portion of trees (stem wood, tops, branches) are moved or 'forwarded' to roadside for processing during forest harvesting.

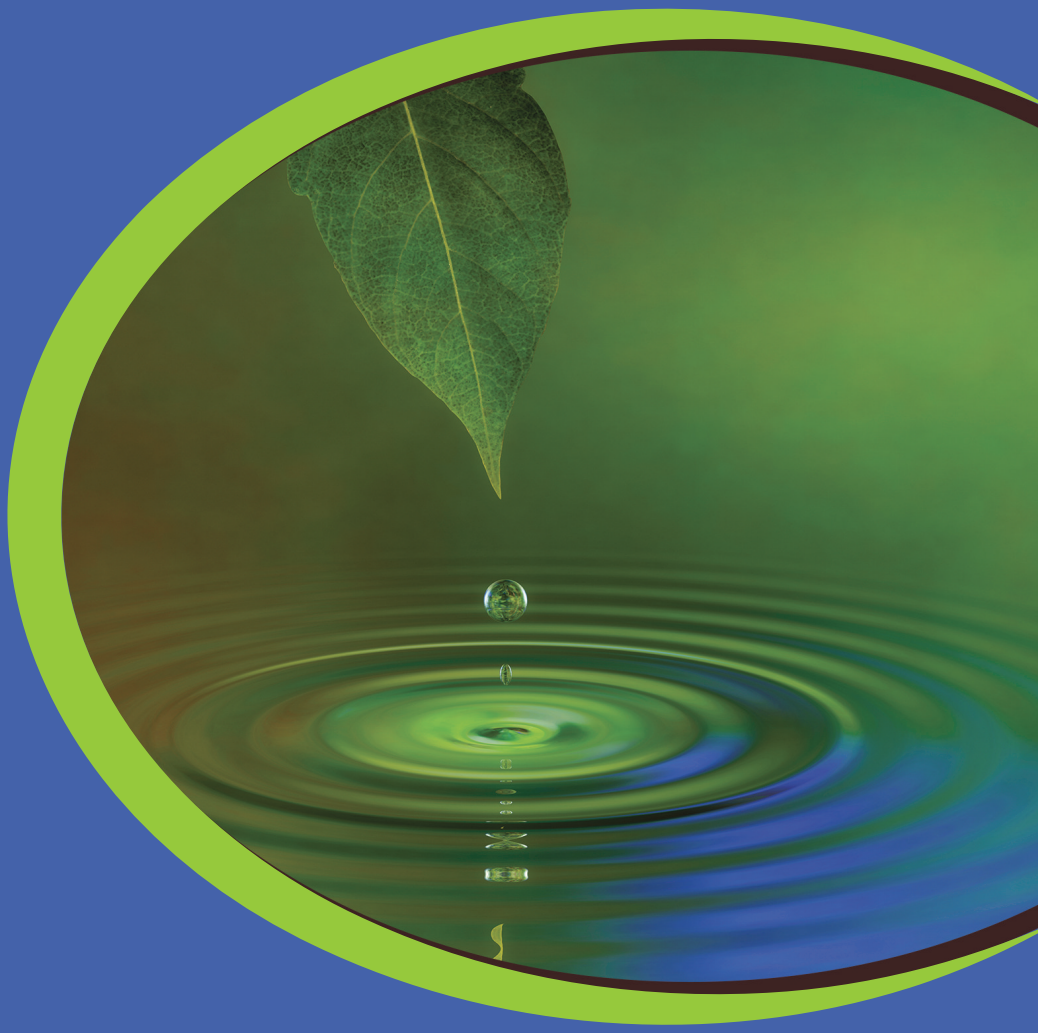
### *Wood Pellets*

'Wood pellets are made by compressing sawdust into small, cylindrical pellets that are 6 or 8 mm in diameter and up to 40 mm long. Lignin, naturally found in wood, holds the pellets together. It is not common in Canada to use additional binders in the manufacturing process to hold pellets together.' Reference: Prevost. G. A Solid Wood Bioheat Guide For Rural and Remote Communities in Ontario. FPInnovations, 2020.

### *Woody Biomass*

Woody biomass is a more finite definition of biomass and includes:

- unused **forest harvest residues**
- wood salvaged after insect outbreaks, wildfires, disease, or other natural disturbance
- unused and untreated wood fibre residues from sawmills or lumber mills



Friends of the Muskoka Watershed