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Abstract

Global recognition of the need for reducing fossil fuel consumption has led to rapid expansion of international bioenergy markets. As jurisdictions begin to design policies to manage the deployment of solid biofuels, a key question remains as to whether existing policies and guidelines are adequate to ensure that biomass harvest and sourcing is conducted in a sustainable manner. This paper aimed to analyze how the existing governance complex applicable to sustainable forest management in Ontario, Canada supports international sustainability goals and leads to achieving relevant standards on the ground. The analysis included both federal and provincial requirements and certification standards relevant to sustainable forest management.

In Ontario, standards are approached through codified and operationally prescriptive rules that articulate detailed performance measures and the underlying management objectives, which foster shared viewpoints between industry and the MNRF. One of the benefits of such policy design is to enable a high level of regulatory intervention by provincial authorities, and a greater propensity for compliance. However, due to the highly stringent nature of policy standards, management options for businesses may be limited and a greater administrative cost is incurred, as detailed operational guidance is required for successful implementation.

Current biomass harvests are conducted under the Ontario SFM and adaptive management framework, which encompasses mandatory planning, stakeholder consultation, monitoring, and self-assessment and government control at the site level to achieve mandated sustainable management goals. Compared to the private certification standards of SFI and CSA the provincial *Stand and Site Guide* contained the most site-specific, complex, substantive and quantifiable operational guidance. The prescriptiveness of the *Guide* also superseded national-level forestry policy in Norway and Sweden, and generally also certification standards applicable in these countries. Private certification schemes were less prescriptive in every policy variable assessed but promote a more comprehensive concept of SFM and act as an additional monitoring tool to ensure that provincial standards are met. Canadian forestry certification standards corresponded to Nordic sstandards. The combined use of the provincial policy framework and private forest certification in Ontario results in comprehensive forest planning, audit, and monitoring to achieve SFM.

It is our hope that this publication will bring insight to readers interested in how sustainable forest management is practiced in Ontario, and which are the near and long-term challenges to governance, following from continued domestic sustainability goals, and international requirements associated with demands for forest biomass for bioenergy use.

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1 Background

Traditional forest products including bioenergy are a key driver of the bioeconomy and have the potential to make significant contributions to international and Canadian strategies aimed at greenhouse gas emission reduction, sustainable development, and energy security. Traditional forest products as timber and pulpwood continue to be the economically most important forest products, while large scale use of wood for new and innovative bio-based products, such as biochemical, bioplastics or biopolymers, or liquid transportation biofuels has not taken off yet, globally or in Canada. However, the global recognition of the need for reducing fossil fuel consumption has led to rapid expansion of international bioenergy markets (Berndes et al. 2003).

1.1 INTERNATIONAL MARKETS FOR HIGH VALUE PRODUCTS

European renewable energy policies have been the main driver for the development of forest bioenergy markets in Canada and Ontario in the last two decades, especially the European Union *Renewable Energy Directive* (2009) as implemented by member states. In Japan, for example, the *Basic Act for Promotion of Utilizing Biomass* was adopted in 2010, with feed-in-tariff (FIT) schemes in place from 2012 (Kitigawa 2018).

Projections estimated wood pellet consumption to reach 22.8 million tonnes and 23.5 M tonnes in European and Japanese/Korean/Chinese markets by 2020, respectively (Bradley et al. 2013). The global wood pellet trade in 2018 was estimated at 23.8 million tonnes. Imports to Denmark, South Korea and Japan increased at least 40% compared to 2017, with the total global increase being 26% (Walker and Strauss, 2019, based on data from FutureMetrics). Industrial pellet demand was estimated at 17.5 million tonnes in 2018, while projections for 2023 are at 29 million tonnes. About 60% of this increase in demand is expected to come from Asia, and 40% from mainly the UK and The Netherlands. Much of the expansion in global biomass trade is expected to be supplied by North American (US and Canada) biofiber exports, which, in 2015 were estimated to make up 28.4% of gross wood pellet consumption by the European Union (5.76 Mt from North America; 20.3 Mt consumption by EU28) (Thrän et al. 2017). A major part, 63%, of Japan's future wood pellet sourcing is expected to come from Canada, while Canada is expected to contribute with less than 2% of the Korean demand (Walker & Strauss, 2019, based on data from FutureMetrics).

1.2 DOMESTIC MARKETS

Significant domestic use of woody biomass for energy production may also be seen in the future, as interest has been stimulated by climate change mitigation strategies. Furthermore, structural market shifts have decreased the demand for forest products and resulted in idled and underutilized existing industrial infrastructure. Ontario's forestry sector contributed up to $19 billion worth of business in the province and supported over 200,000 direct and indirect jobs across 260 Ontario communities (Majumdar et al. 2017). In 2015, these numbers were $15.5 billion and 150,000 jobs (OMNRF 2019c). Since 2001, the overall Canadian forest sector has suffered a broad reduction of over 110,000 jobs (NRCan 2016). Most of the loss in jobs was attributable to the sudden fall in American and Canadian home construction demand from 2005 (Krigstin et al. 2012). The downward trend has been exacerbated by the continued decline in the global demand for newsprint, with Ontario experiencing a loss of over 50% of the pulp and paper capacity. This developed resulted in a surplus harvest volume and an increase in unused chips and residues (Mabee & Mirck 2011) from which bioenergy feedstocks may be derived.

While the use of wood-based bioenergy is not new, current utilization remains low. At the national level, Canadian energy systems are dominated by the use of crude oil and petroleum and natural gas, accounting for over 71% (7668 PJ; IEA Bioenergy 2016) of the total energy supply.

Bioenergy, particularly in the form of wood processing (secondary) residues and pulping liquor are used extensively by forestry industry as sources of local energy and heating, but comprise a small percentage of the total energy pool.

In Ontario, coal-based power production was phased out by 2014, with power supplies subsequently relying mainly on nuclear, hydro and gas (Ontario, 2019). Renewable power generation, other than hydro, contributed with 7% in 2014, including two of six previously coal-fired publicly owned power plants converted to biomass fueling in 2014 (Atikokan (211 MW) and Thunder Bay (306 MW)). However, about 60% of the total energy use is supplied via fossil fuels, with biomass contributing a minor 2% of the province's energy needs (Canadian Energy Systems Analysis Research 2013).

1.3 THE DEVELOPMENT OF A BROADER FOREST BIOECONONY

The development of a broader forest bioeconomy has the potential to rejuvenate rural economies, enable new revenue streams, and spur technological innovation in the sector (Majumdar et al. 2017). This includes new forest biomass uses, in a longer term, and energy uses in the shorter term. The long-term success of the Canadian forest bioeconomy sector depends on satisfying the demand of international markets through export of high value forest products, and not only raw materials. This includes wood pellets based on utilization of residual materials, if they meet technical pellet specifications and national and international sustainability criteria, and are underpinned by cost-competitive business plans.

Although the increased use of harvest residues may increase bark content within wood pellet fuels, which generally command lower prices and generate poor thermal and emissions characteristics, studies have found that wood pellets with up to 30% bark blending produce comparable wear on boilers, and a similar thermal yield to low-bark pellets. Such mixtures would contravene with the performance standards established by both the US and European Union, limiting access to international markets, but could result in an increased export of raw residue feedstocks for pellet production abroad.

Increased mobilization of forest biomass for these purposes would be possible through greater utilization of the approved harvest levels for the province (referred to as Annual Allowable Volume, AAV), and increased removal of woody residues and unmerchantable roundwood for which no market currently exists. However, further mobilization of this resource requires improvements to financial returns as increased fibre availability may only come as a result of expansion of operations into previously remote and marginal areas (e.g. far northern boreal forest) with modest biomass harvest yields and energy density. Higher moisture content and lower commercial value than traditional forest products also imposes cost and delivery challenges (Levin et al. 2011). Although residues are also abundant, accessible on managed sites, and provincially approved, delivery and collection remain significant barriers, and are the primary contributors to increased cost (e.g. see Ralevic et al. 2010), which tighten export prospects if pellet prices weaken in the future (WPAC 2016). Several studies have discussed the need for supply chain innovation to mitigate these challenges, as well as the lack of technology (Mobini et al. 2013, Kumar et al. 2003).

Continuity of policy support has been identified as another factor that is generally critical to successful bioenergy and bioeconony deployment (Smith et al. 2016). Policy support has so far been variable in Ontario. From 2012, Ontario incentivized green energy development under *The Green Energy and Economy Act* (2009), with feed-in-tariffs to stimulate investment and create opportunities for a domestic bioenergy sector. However, this program stopped in 2017. Also, a Thunder Bay power plant is no longer in operation, due to corrosion on the boilers and possibly a

too low demand. It is still a question if it will be put back into operation, in spite of the conversion constituting a major part of a $200 million provincial investment in a biomass innovation cluster for the region (P&PC 2018). The cluster also included innovative biomass research at Lakehead University and the Centre for Research and Innovation in the Bio-economy.

A larger number of federal and provincial policies and programs in Ontario are still related to bioproducts from forest biomass. However, according to Majumdar et al. (2017) improved coordination and collaboration among the relevant government ministries and agencies is needed, if they should be effective and efficient in their support for an emerging bioproducts sector. Majundar et al. (2017) emphasize that it is critical to establish a strategic bioeconomy vision for Ontario, with a clear roadmap for the future of the bioproducts industry.

1.4 SUSTAINABILITY CONCERNS AND POLICIES

Apart from economic viability and policy support, it is critical for investment and public support that environmental and social concerns are adequately addressed. Concerns have been raised regarding the long-term environmental impact of intensive biomass harvest, including the effects of whole-tree and residue harvesting on site productivity and nutrient retention (Hall 2002, Thiffault et al. 2010), and soil physical properties (Kezik and Acar 2016) an water yield (Lattimore et al. 2009). Studies have also identified the importance of coarse woody debris (CWD) in the maintenance of riparian zone structure and function (Waddell 2002), and coarse woody debris and significantly decayed logs are a vital habitat component but are often absent in managed areas (Briedis et al. 2011, Fauteux et al. 2012). There may also be impact on understory mammalian species (Patrick 2013) and biodiversity more generally (Lattimore et al. 2009). Finally, intensive harvesting may potentially impact the forest biomass and soils as a store of carbon (Vanguelova 2010).

In Ontario, sustainability concerns are addressed through long-term strategic policy documents, such as and *Our Sustainable Future*, supported by for example *Ontario's Forest Biofibre Policy* (OMNRF 2013). Supported by the *Forest Resource Assessment Policy, the* Ontario Ministry of Natural Resources' (MNR) *Policy Framework for Sustainable Forests* (Government of Ontario 1994) captures Ontario's commitment to sustainable forest management, which is entrenched in law in the *Crown Forest Sustainability Act* (CFSA). The CFSA includes provisions for the regulation of forest management planning, information, operations, licensing, allocation of forest resources, processing facilities, compliance and enforcement mechanisms required to ensure the sustainability of Ontario's Crown forests. Detailed technical direction for forest management planning is applied through the regulated CFSA manuals. Additionally, the *Ontario Forest Biofibre Allocation and Use Directive* (OMNRF 2013) provide general directions for the allocation and use of forest biofibre from Ontario's Crown forests, according to a number of criteria, such as encouraging the use of forest biofibre for the production of energy and other value added bioproducts; creating economic and employment opportunities for communities and Aboriginal people; finding synergies within the existing forest industry and support the development of emerging bioproducts industries; contributing to the competitiveness and long term viability of the forest industry and assist the forest sector to restructure and diversify; contributing to Ontario's renewable energy commitments; and balancing the social and economic benefits to the people of Ontario with environmental stewardship (OMNRF 2013).

The *Ontario Forest Biofibre Allocation and Use Directive* (OMNRF 2013) defines forest biofibre as tree tops, cull trees or portions of trees, individual trees and stands of unmerchantable and marketable wood, and biomass on disturbed landscapes. It does not include secondary residues from the industry, which are generally already mobilized and in use. Also, it does not include roots

and stumps; the harvesting of these components, especially, may be associated with the long-term loss of nutrient and carbon capital (Lattimore et al. 2009).

Sustainable forest management is an implicit objective of the provincial timber allocation process (through forest tenures, as described below) and the dominant management paradigm in Canada (Luckert and Williamson 2005). *Our Sustainable Future* affirms "healthy, resilient ecosystems" as a top policy priority (MNRSD 2011). Natural Resources Canada defines sustainable forest management as the maintenance of "environmental, social and economic values and benefits over time" (NRCan 2019b), including sustained yield. Hence, biomass harvest must not compromise long-term productivity or other environmental or social goals.

The national policies are embedded in a number of international sustainability commitments. Canada is thus a signatory to the *Montreal Process* (The Montreal Process 2019), *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES 2019), and the *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP 2019).

1.5 SUSTAINABILITY DOCUMENTATION

Documentation of sustainable forest management of feedstock sourcing areas is one of the prerequisites for market access to the international wood pellet trade. Increased concerns about cross-border sustainability issues, particularly with regard to illegal logging and indirect land use change (iLUC) has led to development of new sustainability biomass standards in the European Union, such as the *European Union Timber Regulation* (EUTR) (EU 2010) and policies such as the *Renewable Energy Directive* (EU 2009) with sustainability requirements applicable to liquid biofuels. Such policies may be perceived as representing non-tariff barriers to international trade, but are so far increasing in number. United Kingdom, Denmark, the Netherlands and Belgium have adopted such sustainability requirements also for solid biomass (Stupak & Smith 2018), including comprehensive requirements for sustainable forest management. New EU-wide requirements were adopted in 2016, coming into force from 1 January 2021 (EC 2017), which includes a more limited set of sustainable forest management requirements.

International sustainability initiatives stipulate national monitoring responsibilities and obligations, albeit often non-binding, for meeting a variety of environmental, social, and sustainability goals. Such monitoring forms a basis for documentation of sustainability forest management for entering "green markets". However, also other documentation is required. Governmental legislation is fundamental to reducing potential ecological impacts, and third-party certification has been identified as useful for promoting sustainable production (Hesselink 2010). Monitoring systems with sustainability indicators based upon sound science and stakeholder input may enable a clearer understanding of the trade-offs and possible sustainability impacts associated with biomass extraction. Also, well-defined, site-specific biomass harvesting guidelines can contribute to sustainable on-the-ground performance and tangible improvements in forest condition (Fritts et al. 2014). Given the nascent state and scale of the solid biomass industry within Canada, explicit and comprehensive biomass policies could lower transaction costs for the forestry sector, promote sustainability at integrated levels, and enhance coordination among different governance actors and mechanisms (e.g. policies, laws, guidelines, Best Management Practices (BMPs), certification standards).

1.6 AIMS

As jurisdictions begin to design policies to manage the deployment of solid biofuels, a key question remains as to whether existing policies and guidelines are adequate to ensure that biomass harvest and sourcing is conducted in a sustainable manner. This paper aimed to analyze how the

existing governance complex applicable to sustainable forest management in Ontario supports international sustainability goals and leads to achieving relevant standards on the ground. The analysis included both federal and provincial requirements and certification standards relevant to sustainable forest management. Specific objectives underpinning the aim of this paper were as follows.

- Provide information about Ontario's forest resources, forest management, and governance framework for existing and expected future forest supply chains in Ontario.
- Review and analyze how selected public and private forest management standards are designed for specific sustainability indicators that are key to forest biomass production.
- Assess how requirements for these specific indicators compare to forest management standards of other forest biomass exporting and importing jurisdictions.
- Review measures in place to document implementation (compliance), effectiveness and validation on-the-ground.
- Review and analyze how applicable supply chain control systems are designed to avoid unacceptable sources and mixing in the supply chain.
- Assessing challenges and unresolved issues facing Ontario's forest bioeconomy if governance should meet the standards needed to enter European wood energy markets.

By compliance we mean that recommended practices are being followed, and by effectiveness we mean that sustainability goals are being achieved, and by validation we mean that a causal relationship has been established between a policy and its effect on the ground (Smith et al. 1999).

It is our hope that this publication will bring insight to readers interested in how sustainable forest management is practiced in Ontario, Canada, and which are the near and long-term challenges to governance, following from continued domestic sustainability goals, and international requirements associated with demands for forest biomass for bioenergy use.

2 Material and Methods

2.1 FOREST RESOURCES, MANAGEMENT AND GOVERNANCE

We reviewed current public and private governance measures relevant to forest biomass production and harvesting in Ontario, and described the availability of eligible feedstocks for the domestic and international bioeconomy.

2.2 POLICY ANALYSIS FRAMEWORK

The comparative methodology used in this study builds upon the analytical framework developed by McDermott et al. (2008) and McDermott et al. (2009), which assesses policy prescriptiveness through: a) categorization of policy approach, and b) comparison of threshold requirements for compliance with selected sustainability indicators, after classifying them according to specific policy parameters.

The policy approaches were categorized based on their mandatory or voluntary nature, as well as their substantive, contingent, mixed or procedural nature (Table 1). Substantive policies refer to performance-based approaches that employ specific, quantifiable requirements, while procedural approaches denote plan- or systems-based management requirements to fulfill policy needs. Mixed or elective policy types also exist where policy objectives are stated, but without the substantive quantifiable detail such as size or site characteristics or any procedural details. In this

case, the pathway towards the goal is to be decided in implementation. Finally, contingent approaches base their requirements on governmental policies. Mandatory-substantive policies are the most prescriptive, while voluntary-procedural policies permit the greatest levels of discretion in management.

Table 1. Classification of policy approaches in governance systems (Mansoor et al. 2019, based on McDermott et al. 2008 & 2009 & 2010, Cashore & McDermott 2004).

	Voluntary	Mandatory
Procedural	System or plan based; flexible	System or plan based; flexible
Contingent	Voluntary policy based on government policies; flexible	Mandatory policy based on government policies; flexibility depends on government policy
Mixed	Voluntary goal suggested, but no specific requirements on the pathway	Mandatory goal, but no specific requirements on the pathway
Substantive	Specific requirements listed; flexible	Policy specifications defined; inflexible

Classification parameters for thresholds were an additional policy variable applied under the work of McDermott et al. (2009) to compare national and sub-national differences in policies, using the legislative requirements for "riparian buffer zones" as a case. Classification parameters may include for example stream order, length and width, bank slope, stream flow, and soil characteristics. The number of classes for each parameter refers to the number of boundaries or classes used to define specific management actions for each parameter, and for which appropriate values of protection is prescribed based on a gradation of environmental variables or spatial ranges. The number of used parameter, as well as the number of used classes, indicates the complexity or need for professional judgement and site-specific guidance, and the incorporation of scientific results.

Within our study, the number of parameters used in streamside buffer protection requirements were collected from the *Ontario Stand and Site Guide* (OMNRF 2010) and compared with the national averages collated under McDermott et al. (2009) to appraise guideline adequacy.

Overall, the used approach provides the opportunity to assess a range of domestic and international regulatory schemes applicable to forest biomass harvest and investigate the ecological function, benefits, and risks associated with each governance design.

Moreover, a cross-jurisdictional comparative method enables the identification of gaps and unresolved areas of policy and implementation amongst the Ontario framework and systems abroad. We focused on three elements of institutional design: policy thresholds, evidence of progress on the ground, supply chain controls; and we analyzed the governance of supply chains involving the production, assurance, and export of Ontario's biomass products.

2.3 ANALYZED STANDARDS AND SUSTAINABILITY CRITERIA

Four sustainability indicators were selected for detailed analysis based on predominant concerns for biomass harvest for the short and long term (Thiffault et al. 2010), prevalence amongst international schemes, and existence of thresholds:

- Riparian buffers
- Retention
- Soil erosion and disturbance
- High conservation value (HCV) forest

By retention we mean retention of retention of stand, living tree, residue or coarse wood debris amounts or structures after harvesting.

Analyzed current standards included the following governance approaches among public and multi-stakeholder systems.

- The Canadian Standards Association's CAN/CSA-Z809-16 SFM Standard (CSA 2016).
- The Forest Stewardship Council (FSC) Standard with International Generic Indicators (IGI) (FSC 2015) and FSC Canadian National Boreal Standard (FSC Canada 1994).
- The Sustainable Forestry Initiative's "SFI 2015-2019 Forest Management Standard" (SFI 2015a).
- Ontario Stand and Site Guide (OMNRF 2010)

Note that the Canadian FSC regional standards are currently under revision to create one national Canadian standard (FSC Canada 2018) that adapts the FSC IGI standard (FSC 2015) to national conditions, but the standard is yet only available as a draft.

The policy variables were analyzed directly, with reference to guidelines for biomass harvest and retention recommendations as summarized by the Forest Guild (Evans et al. 2013), in order to describe a range of anticipated and existing potential effects on Ontario's forest ecosystems.

2.4 JURISDICTIONAL COMPARISON

The governmental provincial guidelines of Ontario and applicable forest certification standards were first compared, then governmental regulation and forest certification of Norway and Sweden were analyzed, for the four analyzed sustainability indicators. Next, their compliance with European Union and member state requirements was assessed, as given by the Renewable Energy Directive (RED I, EU 2009), and the adopted revised Renewable Energy Directive (RED II, EC 2017) coming into force from 1 January 2021. We also discussed compliance with national EU member state policies.

2.5 EVIDENCE FOR PROGRESS ON THE GROUND

We summarized and evaluated available monitoring programs and data for documentation of federal and provincial policy implementation, effectiveness and validation on-the-ground, and well as monitoring required by private forest certification systems, including the frequency with which information is collected, the scope of audits, and organizations responsible for forest governance monitoring.

2.6 SUPPLY CHAIN CONTROLS AND ASSURANCE

Supply chain governance was analyzed by documenting chain of custody requirements in the CSA, FSC and SFI standards, with emphasis on three chain-of-custody components: criteria for controversial wood, volume control mechanisms and accreditation requirements. The intent was to appraise the performance of chain of custody values among the three selected certification organizations, and understand the contributions of supply chain integrity to the overall governance environment. The implications of such findings were discussed within the broader context of

Ontario's forest management framework and international trade. In addition to chain of custody standards, accreditation standards for certification bodies were also reviewed.

3 Forest resources, management and governance

3.1 POLICIES REGULATING FOREST MANAGEMENT AND BIOMASS HARVEST

The total forest area in Ontario amounts to 71 million ha. Governance for forest resources evaluated in this paper has focused on management of publicly owned forest land, which is generally referred to as the "Crown land". These forest lands make up almost 90% of Ontario's forests. This policy review furthermore relates to the 45 million ha of central and northern Ontario, which is defined as the so-called "Area of the Undertaking". Removing water, parks, private, First Nations and federal lands, as well as protected areas and non-productive forest from the Area of the Undertaking leaves the 27 million ha of forest, which are considered Crown Productive Forest (OMNRF 2014a) (Figure 1). Private ownership comprises nearly 9% of Ontario's forested land, with these lands mainly located in the southern part of Ontario. They are governed by other measures (https://www.ontario.ca/page/private-land-forestry) than the provincial legislation described here.

Figure 1. Map of Ontario showing the "Area of the Undertaking", as well as portions of the province that are Crown, federal, First Nations, private, and parks or protected lands (OMNRF 2019a; area available for harvest).

Under the Canadian constitution, provincial governments are the designated authority over lands and natural resources, including the responsibility to administer their own regulations and forest management. Provincial jurisdictions regulate forest management, utilization standards, and all aspects of access to and management of forest resources through various laws. In Ontario, a comprehensive framework of strategic initiatives and regulatory legislations govern the forestry sector (Table 2). In addition to provincial forest sector regulatory frameworks, national legislation, such as the *Federal Fisheries Act* (1985), *Species at Risk Act* (2002), *Migratory Bird Convention Act* (1994), and *Plant Protection Act* (1990) (Table 2), apply to all forestry operations. The federal acts also address the management needs of federal forests, indigenous reserves, and steer the development of sustainability goals, research, development, investment, and trade.

Table 2. Strategic documents, legislation and policies that provide for strategic direction and regulation of the forest sector of Ontario, including both provincial (a-m) and federal (n-q) documents.

Strategic direction	Intent
Horizons 2020[a]	Strategic vision for the Ministry of Natural Resources and Forestry (MNRF).
Ontario's Biodiversity Strategy, 2011[b]	Provide guidance and a common focus for biodiversity conservation in Ontario.
Land Use Planning: • Ontario's Living Legacy Land Use Strategy (Lands for Life) (OLL)[c] • Keeping The Land –A Land Use Strategy for the Whitefeather Forest (WF)[d] • Far North Act, 2010 (FNA)[i]	OLL: Provides broad land use classifications, and outlines many new parks, conservation areas, and enhanced management areas. WF: Produced by Pikangikum First Nation and prepared in collaboration with the Ontario Ministry of Natural Resources; first community-based Land Use Plan that has been approved in Ontario. FNA: Provides for community based land use planning in the Far North. MNRF responsible.
Growth Plan for Northern Ontario, 2011[e]	A 25-year plan that provides guidance to align provincial decision-making and investment for economic and population growth in Northern Ontario.
Regulations	**Intent**
Crown Forest Sustainability Act (CFSA), 1994[f]	Provides 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. MNRF responsible.
Environmental Assessment Act (EAA), R.S.O. 1990[g]	The betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment. MECP responsible. Declaration Order MNR-75 permits access, harvest, and renewal and maintenance activities in the Area of the Undertaking.
Endangered Species Act (ESA), 2007, including the 230/08 regulation "Species at Risk in Ontario List" and O. Reg. 242/08: General[h]	To identify species at risk based on the best available scientific information, including information obtained from community knowledge and aboriginal traditional knowledge; to protect species that are at risk and their habitats, and to promote the recovery of species that are at risk; to promote stewardship activities to assist in the protection and recovery of species that are at risk. MNRF responsible.
Ontario Forest Tenure Modernization Act (OFTM), 2011[j]	Creates a more economically efficient allocation and pricing system (wood use, new entrants, competitive wood costs, economic viability, good governance practices, reducing role of government, greater separation of mills from the management of forests); provides opportunities for meaningful involvement by local and Aboriginal communities; provides for the sustainability of the Crown forest. MNRF responsible.
Other related Acts regulating forestry, foresters and forest ecosystems: • Environmental Bill of Rights, 1993 (EBR)[k] • Algonquin Forestry Authority Act, R.S.O. 1990 (AFA)[l] • Professional Foresters Act, 2000 (PFA)[m]	EBR: To protect, conserve and, where reasonable, restore the integrity of the environment by the means provided in this Act; to provide sustainability of the environment; and, to protect the right to a healthful environment. AFA: The Algonquin Forestry Authority (AFA) is the Crown Agency responsible for Sustainable Forest Management in Algonquin Provincial Park. PFA: Created the Ontario Professional Foresters Association which regulates the practice of professional forestry and governs its members.

• Federal Fisheries Act, 1985 (FFA)[n] • Migratory Birds Convention Act, 1994 (MBCA)[o] • Plant Protection Act, 1990 (PPA)[p] • Species at Risk Act, 2002 (SARA)[q]	FFA: The federal government has jurisdiction over Canada's inland and coastal fisheries; the Fisheries Act is an important tool for the sound management of Canada's fisheries resources and supporting habitat.
	MBCA: Contains regulations to protect migratory birds, their eggs, and their nests from hunting, trafficking and commercialization through permitting.
	PPA: To protect plant life and the agricultural and forestry sectors of the Canadian economy by preventing the importation, exportation and spread of pests and by controlling or eradicating pests in Canada.
	SARA: Prevent wildlife species from being extirpated or becoming extinct; to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity; to manage species of special concern to prevent them from becoming endangered or threatened.

[a] http://apps.mnr.gov.on.ca/public/files/er/mnrf-horizons-2020_en.pdf
[b] http://ontariobiodiversitycouncil.ca/ontarios-strategy/
[c] http://ontora.ca/ref/gov/mnr-policies-procedures/ontarios-living-legacy/
[d] http://www.whitefeatherforest.ca/stewardship/our-land-use-strategy/
[e] https://www.placestogrow.ca/index.php?option=com_content&task=view&id=53
[f] https://www.ontario.ca/laws/statute/94c25
[g] https://www.ontario.ca/laws/statute/90e18
[h] https://www.ontario.ca/laws/statute/07e06 (ESA), https://www.ontario.ca/laws/regulation/080230 (230/08), https://www.ontario.ca/laws/regulation/080242 (242/08)
[i] https://www.ontario.ca/laws/statute/10f18
[j] https://www.ontario.ca/laws/statute/11o10
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[p] https://laws-lois.justice.gc.ca/eng/acts/p-14.8/
[q] https://laws-lois.justice.gc.ca/eng/acts/s-15.3/

In Ontario, the *Crown Forest Sustainability Act* (CFSA) (Table 2) defines sustainability as "long-term Crown forest health" consistent with the principles of "large, healthy and diverse Crown forests", and the "long term health and vigor" of Crown forests through practices that emulate the natural disturbance and landscape patterns; this Act is a legislative commitment to the practice of sustainable forest management. The CFSA applies to all Crown land in Ontario, and relies on four regulating manuals that provide detailed requirements:

- Forest Management Planning Manual (FMPM)
- Forest Operations and Silviculture Manual (FOSM)
- Forest Information Manual (FIM)
- Scaling Manual (SM)

The CFSA thus provides for the regulation of forest planning; information management and exchange; forest operations, licensing, trust funds, processing facilities, and remedies and enforcement; and independent forest audits.

The CFSA also provides a system of "forest tenures", or more simply "tenures", which constitute the legal arrangements that define rights and responsibilities for the management and use of Crown forests. Access to Crown forest resources is provided for under four formal arrangements (OMNRF 2019b; Using trees from Crown forests for commercial purposes):

- Sustainable Forest License (SFL)
- Forest Resource License (FRL)
- Wood Supply Agreement (SA)
- Arrangement to buy trees from an existing licensed harvester (LH).

The CFSA tenures are thus based on over 40 defined forest management units (FMU) and harvest volume (Table 3, Figure 2). SFLs allow license holders "to harvest trees within a defined

management area for a period of 20 years". Furthermore, "SFLs cover large areas of land and come with a high degree of responsibility for forest management and forest management planning". FRLs allow license holders "to harvest trees, generally within a smaller area of land than a SFL for a period of up to 5 years". Wood supply agreements (SAs) can also be obtained from the Crown by mills and other forest-dependent companies to retrieve a fixed volume of timber.

Table 3. Duration of Ontario forestry licenses and utilization and harvesting compliance requirements (OMNRF 2019b; Using trees from Crown forests for commercial purposes).

	Sustainable Forest License (SFL)	Forest Resource License (FRL)	Wood Supply Agreement (SA)
Maximum duration	20 years	5 years	Volume-based
Harvesting and utilization	Harvest and use of all Crown trees within the license area	Harvest and use of all Crown trees within the license area	A specified amount of Crown owned trees from specific forest management units (FMU)
Compliance requirements	Harvest operations must be consistent with the approved forest management plan	Harvest operations must be consistent with the approved forest management plan	Harvest operations must comply with terms and conditions between the Crown and mill (agreement holder)

The forest tenure system is at present undergoing a modernization to improve new companies' access to unused wood supply; local and Indigenous community involvement; information quality and its accessibility; sustainable forest management; and the economic viability of the forest sector (OMNRF 2019c). New types of licences include so-called Enhanced Sustainable Forest Licences and Local Forest Management Corporation (Figure 2).

The different resource license applicants are required to submit a detailed forest management plan governed under the *Forest Management Planning Manual* (FMPM), which must include identification of species and values at risk, long-term management direction, and models to determine the impact on yield, growth rate, regeneration, and other relevant indicators (OMNRF 2014b). Forest management plans (FMP) establish sustainable wood supply and considerations for the social benefits conferred by management. Forest management plans are prepared and approved for a 10-year period by a professional forester and must incorporate input from the public, stakeholders, and communities. The different forms of Ontario forestry licenses vary with respect to duration and management responsibilities (Table 3).

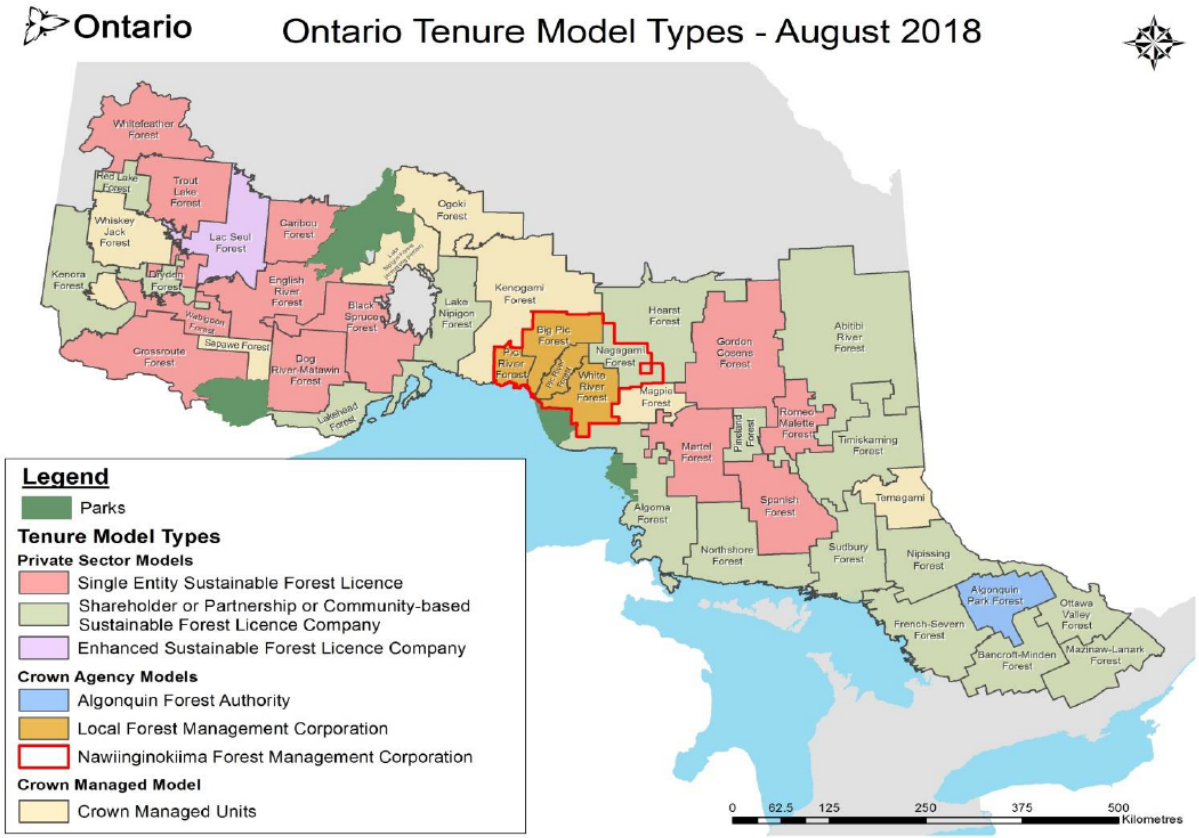

Figure 2. Map of Ontario tenure model types for Sustainable Forest Licences (SFLs) as of August 2018 (van Kerkhof 2018, OMNRF 2019c).

For the implementation of the FMPM, management must comply with five management guides:

- Forest Management Guide for Boreal Landscapes, and Forest Management Guide for Great Lakes-St. Lawrence Landscapes.
- Forest Management Guide for Conserving Biodiversity at the Stand and Site Scales
- Forest Management Guide to Silviculture in the Great Lakes-St. Lawrence and Boreal Forests of Ontario
- Forest Management Guide for Cultural Heritage Values.
- Management Guidelines for Forestry and Resource-Based Tourism.

1.

2. These guides provide guidance for the forest management at the landscape, stand, and site scales, including silviculture, tourism and cultural heritage. Compliance with the guideline requirements is mandatory and compliance is assessed regularly through self-reporting and field audits. The top-down structure is designed to reflect the coarse and fine filter concept for the conservation of biodiversity as presented by Hunter (1990). Coarse filter regulation provides adequate protections for most ecological and landscape objectives at larger temporal or spatial scales, while the complimentary fine filter regulation addresses special habitat areas or social-economic needs beyond the scope of the coarse filter. The forest management guides are written in great detail in a system that comprise three different approaches to guidance, with overarching "standards" that are to be followed as written, "guidelines" that may be implemented under professional supervision and application of local knowledge, and "best management practices" that offer site-specific recommendations and up-to-date findings.

Detailed guidelines for biomass harvest are found in the *Forest Management Guide for Conserving Biodiversity at the Stand and Site Levels* (henceforth referred to as the "*Stand and Site Guide*") which addresses protection for soils, tree retention, understory vegetation, hydrology, and wildlife (OMNRF 2010). However, the overall allocation, use and guidance for biomass harvest remain under the regulation of the broader provincial governance framework for forest management and do not constitute "biomass-specific" guidance.

Ontario forest policy and legal framework is subject to a rigorous Environmental Assessment Process (Table 2), bound by the *Declaration Order MNR-75, Environment Assessment Requirements of Forest Management on Crown Lands in Ontario*, which delineates a number of assessments and activities that must be conducted before forest operations begin. For example, forest management plans may only be approved after comprehensive stakeholder processes, involving local citizens, aboriginal communities, and other stakeholders (OMNRF 2014d; Environmental Assessment Requirements for Forest Management on Crown Lands in Ontario).

3.2 FORESTRY CERTIFICATION

Private certification schemes are voluntary regulatory instruments that define sustainability obligations that are often above and beyond provincial government forest management, monitoring and auditing requirements. While not legally binding, certification bodies establish independent sustainability standards through stakeholder agreed-upon principles and criteria, performance objectives, or other indicators which must be verified through third-party assurance. Typically, the certification process is separated into three stages, allowing tiered compliance to certification standards. Forest management companies that seek certification must document their operations meet sustainability standard requirements prior to the initial audit (certification/first audit), undergo continual improvements should partial compliance occur, and maintain timely closure of preconditions and corrective action requests during each subsequent year of certification. This ultimately allows companies to demonstrate their commitment to sustainable forest management (SFM). In the FSC system, certificates are valid for a total of 5 years (FSC 2019a), while SFI and CSA certificates expire within a 3-year term (SFI 2019, CSA 2019). All three certification systems utilize annual surveillance audits to ensure routine compliance with their respective sustainability criteria.

Within Ontario, over 24 million ha of SFL land is certified; all three available systems are pursued, including FSC, SFI, and CSA. All three systems are recognized by the Ontario Ministry of Natural Resources and Forestry as valuable for marketing purposes, and both SFI and CSA are endorsed by the Program for the Endorsement of Forest Certification (PEFC 2019). Forest management units within Ontario are certified by one individual or multiple certification schemes (Figure 3).

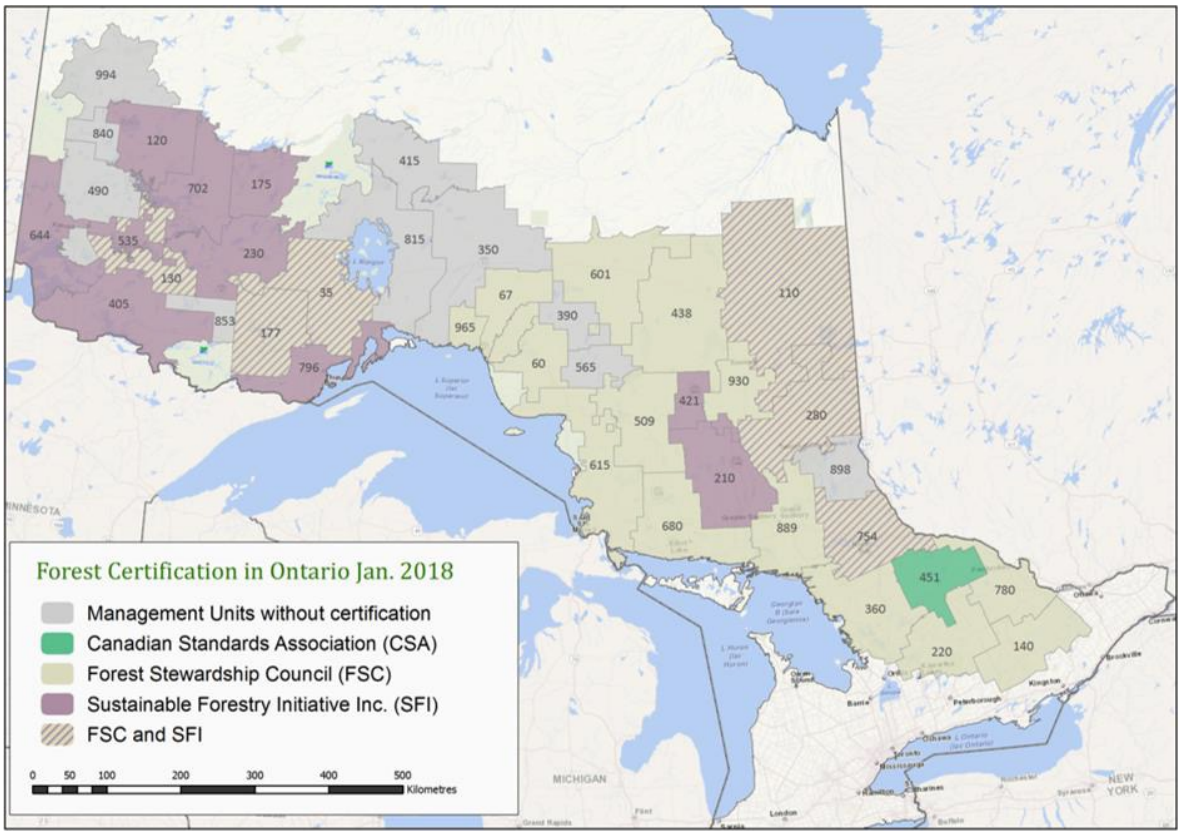

Figure 3. Certified forest land base in Ontario, Canada, by forest management unit (van Kerkhof 2018).

3.3 FOREST PRODUCTS AND BIOENERGY FEEDSTOCK SUPPLY CHAINS

Clearcutting utilizing full tree harvest (FTH) operations, referring to the felling and forwarding of trees with branches and tops intact to the roadside or landing for processing (delimbing, topping and comminution), is the primary harvest method in Ontario (Puttock et al. 2005, Ghaffariyan et al. 2017). This method, also common to western Canada, employs a higher skidding and landing requirement compared to cut-to-length (CTL) systems, where processing occurs near the stump. The use of CTL systems results in the deposition of residues within harvest trails and logged blocks, whereas FTH produces a greater volume of residues at roadside, which are typically piled for natural decay or disposed by burning. Full tree harvest system residues such as slash or delimber primary residues may also be returned to the logged block, although at greater cost than incineration. Although the level of biomass recovery varies with site- and operation-specific factors including recovery equipment, access to sites, seasonal factors and species characteristics, three sample sites in northern Ontario black spruce forest type evaluated by FPInnovations demonstrated similar levels of biomass recovery, and an equal distribution of roadside, cutover slash and standing residual trees (Ralevic et al. 2010).

Raw materials retrieved from primary harvest are transported to wood processing facilities. In the forest products manufacturing sector, roundwood obtained from harvest are converted into primary forest products such as veneer and lumber at the sawmill; lower grade roundwood or pulpwood are converted into fiber boards and pulp at pulp mills. Under the bioenergy pathway, wood materials are chipped, stored and dried, lowering the moisture content prior to pelletization and energy conversion. Since 2015, five pellet mills in Ontario have been in operation, enabling an

aggregate production capacity of 246,000 tonnes yr^{-1}. Three additional plants have been proposed, although one pellet mill has also been idled owing to operational and economic difficulties. Ontario mills make up 12% of national pellet production (Krigstin et al. 2016) and are geographically concentrated in the northeastern portion of the province in the Thunder Bay area, which is ecologically classified as the Boreal Forest. The Boreal Forest region is covered by coniferous and mixed wood forests, and is the most actively managed, comprising 58% of the Area of Undertaking (OMNRF 2014a). Operations located in the southeastern portions of Ontario encompassing the Great Lakes - St. Lawrence forest region are characterized by a high proportion of hardwood (deciduous) species and white and red pine, and consequently are harvested using shelterwood harvest systems. Management within this area occurs at a significantly smaller scale and without the presence of a major forest industry, largely comprised of several family-run operations.

International forest biomass supply chains are shaped by their intended export market and corresponding feedstock specifications. International solid biofuel markets are associated with two types of pellet products: 1) those used in heating and institutional markets such as Japan, Korea, and the United Kingdom, and 2) high-grade pellets utilized for energy conversion, most prevalent in the European continent and Nordic regions. Some 84% of the Canadian production is exported for energy markets based at the Europe continent and the United Kingdom (STATCAN 2019; see also Thrän et al. 2017). Exports to Japan saw a fourfold increase from 2014 to 2016 but were still only one sixth of the exports the UK (WPAC 2016). Wood pellet markets influence the level of integration with existing, conventional forest supply chains. Where the market permits, there may be deployment of stand-alone pellet supply chains, or varying levels of integration to leverage mill harvest residues as feedstocks and the use of excess heat and storage facilities for processing prior to pelletization.

3.4 ONTARIO'S WOODY BIOMASS RESOURCES

Potential woody biomass sources available for bioenergy feedstocks in Ontario include: 1) primary, secondary and tertiary residues, 2) unmerchantable and low-quality timber from species with no current markets, such as birch, aspen and poplar, and 3) high-value softwoods also used to produce forest products.

Primary residue feedstocks derived from forest harvesting operations and secondary residues from existing manufacturing facilities are the least expensive and most readily accessible sources of woody biomass. Primary residues are defined as harvesting residues (tops, branches and leaves), while secondary residues refer to by-products of manufacturing processes, including black liquor, bark, and sawdust. Tertiary residues are reclaimed sources retrieved from demolition, construction and packing industries. Harvesting residues and sawmill residues are considered to be the principal sources within Canada (Krigstin et al. 2012), and estimates indicate an abundant supply within Ontario (e.g. Mabee & Mirck 2011).

The Ontario Annual Allowable Volume (AAV) of approximately 30 million cubic meters of timber per year (National Forestry Database, 2019) has not been achieved as a result of various factors affecting the economic competitiveness of the forestry sector (Figure A1); annual harvest in 2017-18 was about 15 million m^3. Utilization of this resource within the context of the broader forest bioeconomy is a strategy currently endorsed by the *Ontario's Biofibre Policy* (OMNRF 2013). If the AAV potential were achieved, it is anticipated that the primary, secondary and tertiary residues produced by an expanded traditional forestry sector would be available for bioenergy feedstocks. Pare et al. (2016) estimated that the bioenergy-to-roundwood ratio for Canada is 36%; if this ratio applies to Ontario, one might estimate 15 million m^3 annual harvest to produce 5.4 million

m^3 of biomass for bioenergy, while harvesting at AAV levels would produce 10.8 million m^3 of energy biomass (see also Pare et al. 2011).

Mabee & Mirck (2011) estimated approximately 4.5 million tonnes (oven-dry) of lignocellulosic feedstock available for bioenergy conversion in Ontario, one-third of which consisted of hardwood from the Great Lakes - St. Lawrence region and two-thirds softwood from the Boreal Forest region. A spatial query conducted on the BIMAT's forest residue dataset also estimates an annual availability of 0.9 million tonnes of hardwood and 3.5 million tonnes of softwood primary residues on roadside within Ontario (BIMAT 2019). Clearcutting systems, which make up 84% of provincial harvest area, would yield the largest volume of residues and are the primary source of woody biomass fuel supplying provincial power generation.

The financial benefits of full tree harvest residue recovery and existing supply supports a strategy of the development of integrated supply chains for the production of wood pellets, rather than stand-alone operations based on the collection of primary residues scattered across a cutblock. Economic considerations are crucial, as illustrated by Lloyd's cost analysis (2014), which noted that as pellet production increased in British Columbia, a higher harvest residue composition was required, thus raising the price. The relatively high cost for feedstock collection and limited availability will provide fiscal challenges to pellet mills in Ontario, and thus raise the importance of fiscal considerations in the deployment of future supply chains.

4 Results of policy analysis

4.1 RIPARIAN BUFFERS

4.1.1 CAN/CSA-Z809-16 National Boreal Standard of Canada

While none of the CSA Z809-16 standards provide operational prescriptions for the use of riparian buffers, Criterion 6.3 assures hydrological conditions through mandating "a proportion of forest management activities [to be] consistent with prescriptions to protect identified water features". The clauses within 6.3.3.3 Element 3.2 further emphasize the importance of water quality and quantity, encouraging forest managers to use detailed maps of surface water and wetland systems along with considerations for best management practices to reduce adverse impacts on water quantity and quality. Criterion 6.3.2 - Ecosystem condition and productivity - also falls under the general scope of riparian protection as management must minimize impacts from disturbance such that they "do not compromise ecosystem condition and productivity". The criterion also encourages the development of operational guidelines for sustainable removal of biomass and thus represents a system-based mandatory procedural requirement.

4.1.2 FSC (IGI and Boreal National Standard)

Both international and national FSC principles and criteria address riparian protection. Hydrology is listed under the FSC international generic indicator of Principle 6, which states that forest management activities must "maintain, conserve and/or restore ecosystem services and environmental values of the Management Unit". The need for riparian protection is further articulated under the Criterion 6.7, which requires that "the organization shall protect or restore natural water courses, water bodies, riparian zones and their connectivity". These reflect a mandatory procedural requirement and a minimum level of protection upon which the nationally adapted standards are built.

Under the National Boreal Standard, riparian protection is expanded under Principle 6 - Environmental Impact. Indicator 6.3.17 states that "Forests surrounding or adjoining permanent water bodies are protected by riparian reserves that exclude all forestry activity", and requires an

inner riparian reserve of 20 m from the treed edge of permanent water bodies. Additional buffers may be applied to conserve habitat and social values but must meet a minimum of 45 meters, on average, from the end of the inner riparian reserve. As managers do not have the flexibility in determining the inner buffer-zone width, the FSC National Boreal Standard is classed as a mandatory substantive policy.

4.1.3 SFI 2015-2016 Forest management standard

Both Principle 3 and Objective 3 of the 2015-2019 SFI standard are relevant to riparian area protection and mandates program participants to develop written policies to achieve "protect[ion] of water bodies and riparian areas" including compliance with best management practices for water quality protection. In addition, applicants must meet and exceed all jurisdictional water quality laws within Canada and from US EPA programs (Performance measure 3.1), and implement programs, plans, mapping and documentation of plans to protect riparian areas. SFI standards can therefore be best described as both mandatory procedural and mandatory contingent, owing to their planning component and reliance on managers to develop their own programs when government best management practices are absent.

4.1.4 Ontario Stand and Site Guide

Riparian protection is addressed through an "area of concern" (AOC), which designates sites of significant ecological importance from which fine filter direction is applied to mitigate the potentially negative effects of management. The riparian AOC, guidelines further specify limitations for the acceptable level of disturbance and prohibit harmful activities. Several mandatory requirements are set forth in Section 4.1.1 - Standing waters: lakes and ponds - which provide five slope gradient-based AOC boundaries ranging from 30 m to 90 m. Within the AOC, no machine travel or felling of trees are permitted within the inner 3 m of the bank and equipment maintenance, such as changing oils or washing may only be conducted 15 m or farther from the edge of the water body; noting that 15 m is a special case for low potential sensitivity ponds and streams. For all other waterbodies, and the majority on the landscape, the minimum distance is 30 m (e.g. see p. 41 of *Stand and Site guide*). Section 4.1.2 specifically prohibits harvesting, renewal, or tending operations within the AOC that damage river or stream beds or banks or deposit sediment in water bodies; disturbance of the forest floor that leaves ruts; or significant patches of exposed mineral soil should "be promptly rehabilitated to prevent sediment from entering a water feature". Management within the AOC is constrained by Section 4.1.2 requirements for retention of downed woody materials and maintenance of stand residual structure.

4.2 RESIDUAL RETENTION AND COARSE WOODY DEBRIS

4.2.1 CAN/CSA-Z809-16 National Standard of Canada

Stand and residue retention is covered within Criterion 6.3.1.3 Element 1.1 - Ecosystem diversity - which recognizes the degree of within-stand structural retention as a core indicator. Coarse woody debris is also an indicator for Criterion 6.3.3.3 Element 3.1 - Soil quantity and quality - where CWD is defined as both downed woody material and as standing trees left to decompose. However, no threshold values are established nor other requirements other than the need to maintain a range of records and information of retention procedures. Hence, the policy relies on the mandatory procedural requirement for regulation.

4.2.2 FSC (National Boreal Standard)

Requirements for residue retention are listed under multiple principles and criteria. Indicator 6.3.10 provides a quantifiable retention threshold, in that normal and salvage operations must include 1) a remaining post-harvest residual representative of pre-harvest conditions in structure, size and species, 2) long-term retention horizon of at least one rotation, and 3) total amount of

residual structure from harvest operations retained to be 10-50% by area. Principle 6 concerns environmental impact and its intent may only be passed when "residual retention is greater than 25% unless determined otherwise on the basis of broad consensus". Under Principle 5, Indictor 5.6.2, managers must also determine adequate harvest levels to align with the sustainability principles listed under the standard, including "long-term residual retention at the stand level". Indicator 6.1.8 also requires applicants to perform benchmarking to measure the amount and coverage of coarse woody debris, snag, and live-tree density, but there are no limitations on the level of sources of debris that can be collected. Since the actual retention area is dependent on the results of the pre-industrial condition analysis procedures instructed under Criterion 6.1, indicator 6.1.5, retention requirements can be classified as mandatory substantive. Criterion 6.1 concerns environmental impact assessment.

4.2.3 SFI 2015-19 Forest Management Standard

Harvest residue and residual stand retention is required under Objective 2 - Forest Health and Productivity - Performance measure 2.3, where program participants are required to "implement forest management practices to protect and maintain forest and soil productivity", including the retention of vigorous trees during partial harvesting. Coarse woody debris and skid trails are listed under the measure as indicators for restoration of post-harvest conditions conductive to maintaining site productivity. As there are no explicit requirements for the development of plans or documents for retention, SFI residue retention and CWD requirements are only applicable after compliance with provincial laws (Objective 9) and are mandatory contingent.

4.2.4 Ontario Stand and Site Guide

Section 3.0 - Conserving Biodiversity, Management at the stand, multi-stand and meso-landscape scales - provides operational thresholds for residual retention (quantitative criteria for residual forests are provided in Section 3.2.2.1). Operational plans "will ensure" that any point in a planned clearcut will retain at least 25 ha of mapped residual forest within a 500 ha circle or hexagon about that point (Section 3.2.2.2). New clearcut harvest areas shall contain 0.5 ha within each 50 ha circle or hexagon across the block, which can be an AOC, a specific habitat function, etc. Wildlife trees within clear-cut operations must be retained at a rate of 25 stems ha^{-1} with a minimum of five large living trees standing on the landscape. Forest management plans written prior to the publication of the *Stand and Site guide* followed the *Ontario Forest Management Guide for Natural Disturbance Pattern Emulation* (ONDPE) (OMNR 2001) requires that 10-36% of the forest area be retained within a disturbance boundary. Disturbance sizes defined by the ONDPE guide range from a few hectares to more than 10,000 ha. For plans written without the *Landscape Guide*, operational planning for clearcuts "will ensure" 20% or more retention in the planned harvest areas, based on a 500 ha moving sampling frame (Table 3.2c in the guide). The inflexible and well-defined approach is illustrative of mandatory substantive policy, which is the most prescriptive policy type.

4.3 SKID TRAILS

4.3.1 CAN/CSA-Z809-16 National Standard of Canada

No operational guidelines or standards for skidding operations are present in the CSA standard. However, Criterion 6.3.3 - Soil and Water - encourages careful infrastructure development to "minimize any adverse impacts of these activities". This represents a voluntary procedural standard.

4.3.2 FSC (National Boreal Standard)

The requirements of Indicator 6.5.1 indicate that ground rules or standard operating procedures (SOPs) must be developed to abate soil rutting and compaction, including guidelines on the use of "mitigation of modifications to surface and sub-surface drainage caused by roads, road

embankments and skid trails". SOPs must also be implemented to ensure the regeneration of abandoned landings, skid trails and roads. The use of written guidelines is a mandatory, plan-based procedural policy.

4.3.3 SFI 2015-19 Forest Management Standard

Skid trails are a core indicator for Performance measure 2.3 and 3.2 under Objective 2, Forest Health and Productivity. There is no detailed guidance for use of skid trails used in biomass harvest other than skidding operations near riparian zones. A mandatory procedural requirement is observed as participants must develop a program or plan-based measure for the layout and construction of skid trials near waterbodies.

4.3.4 Ontario Stand and Site Guide

The extent of skidding regulations is based on the identified species habitat. Skidding operations during the winter season must observe a 150 m buffer from gestation and oviposition sites in snake habitat and 151-300 m during the summer nesting period. Best management practices for turtle habitat encourage a 150 m no-skid zone. As buffer boundaries are well-defined, skidding directions are mandatory substantive.

4.4 HIGH CONSERVATION VALUE FORESTS (HCVF)

4.4.1 CAN/CSA-Z809-16 National Standard of Canada

Element 1.4 - Protected areas and sites of special biological, geological, heritage, or cultural significance - defines HCVF areas as "sites of biological, heritage, or cultural significance" which may be identified via "a wide range of criteria". In addition to the maintenance of a degree of habitat protection for selected focal species and those at risk (6.3.1.3, Element 1.1), applicants must identify HCVF sites within the defined forest area, "implement management strategies appropriate to their long-term maintenance" and respect protected areas, which thus constitutes a mandatory procedural policy.

4.4.2 FSC (National Boreal Standard)

Requirements for High Conservation Value Forests are listed under Principle 6: Environmental Impact, Principle 7: Management Plan, and Principle 9: High Conservation Value Forests. HCVFs are identified through the fulfillment of four criteria: forests containing high concentrations of biodiversity values; areas that contain rare or endangered species; areas that provide basic services of nature in critical situations; and forests that are fundamental to meeting the basic needs of local communities. Applicants must recognize and appropriately manage HCVF areas through the assessment and outside review of the forest management plan to determine the presence of HCVFs, including consultation with stakeholders and other interested parties. Areas found to contain HCVFs are prohibited from conversion into plantations or for non-forest land uses other than access roads. Verification based on documentation of the identification process and results represent a mandatory procedural policy.

4.4.3 SFI 2015-19 Forest Management Standard

Objective 4 - Conservation of Biological Diversity - provides measures for HCVF as the management of "Forests with Exceptional Conservation Value". Successful compliance with Performance Measure 4.2 is contingent on the development of programs to protect threatened and endangered species, locate communities of Exceptional Conservational Value, and support for plans and programs aimed at conservation of old-growth forests within the area of forest tenure. The use of programs and plans are listed as an indicator for fulfilment of the performance measure indicates a mandatory procedural approach.

4.4.4 Ontario Stand and Site Guide

As the *Stand and Site guide* is designed to conserve biodiversity and conserve habitat, the term High Conservation Value Forest does not apply as a separate criterion, as the guide provides species-specific regulation and AOC prescriptions. However, Section 3.2 requires development of "conditions on regular operations to maintain S1, S2, and S3 Natural Heritage Information Centre (NHIC) vegetation communities, or other uncommon vegetation communities" which are likely to occur. Examples of NHIC communities include: S1 -- Jack Pine - White Cedar - Low Calamint Treed Alvar Grassland Type; S2 -- Jack Pine - White Cedar - Common Juniper Treed Alvar Shrubland Type; S3 -- White Cedar - White Spruce - Philadelphia Panic Grass Treed Alvar Grassland Type (ONHIC 2019). It seems this approach aligns well with a significant subset of High Conservation Value Forests typically identified through a certification process.

Under the *Ontario Endangered Species Act* 2007 (ESA, Table 2), all species listed as endangered or threatened are recognized as provincially featured species, and their killing, harassment, capture or transport at any life stage is prohibited. The ESA also prohibits the destruction of habitat for any such species. Direction for habitat regulations developed by the ESA supersedes the direction presented in the guide and must be complied with. Regulations for *Species at Risk in Ontario* listed under regulation 230/08 (Table 2) are also provided by the *Stand and Site guide* and subject to the requirements of the Forest Management Planning Manual. As applicants must demonstrate and identify all existing and potential species at risk under the FMPM, conservation requirements under the *Stand and Site Guide* are mandatory procedural.

4.5 COMPARISON OF CLASSIFICATION PARAMETERS

The number and nature of classification parameters employed within individual policies demonstrates the degree of site-specific guidance and is a key indicator of regulatory complexity and incorporation of scientific research. Following the analysis by McDermott et al. (2009) to identify relationships for regional and sub-regional variation in the level of riparian zone classification and management restrictions, our report aims to understand how the streamside riparian buffer protection under the *Ontario Stand and Site guide* compares globally and to compare its policy complexity with other jurisdictions.

Classification parameters for riparian protection include for example, stream order, length and width, bank slope, stream flow, and soil characteristics (McDermott et al. 2009). *The Stand and Site Guide* applies three broad stream classes for the parameter buffer sensitivity: high, medium and low potential sensitivity streams (HPS, MPS and LPS), determined by sub-parameters such as the presence of fish, fish habitat, catchment area, and distance from larger bodies of water. Four AOC prescriptions as buffer width are offered for HPS streams, based on slope of the bank side measured in degrees and percentage. The recommended buffer width (AOC) ranges from 30 m to a maximum of 90 m, and MPS streams are assigned a single 30 m AOC (see Table 5). The system thus uses four sub-parameters (fish, fish habitat, catchment area, and distance from larger bodies of water) to determine another parameter, buffer sensitivity, which together with slope are used to determine the management prescriptions, i.e. the buffer width (size of AOC).

For general comparison, the guide's streamside stream classification categories are higher than the global average, and are similar to those employed in the United States (Table 4). In operational practice, a higher level of discretion is required, and HPS zones must be identified based on results supplied by provincial land class inventory and species distribution. For example, the *Ontario Stand and Site Guide* prescribes a 50 m AOC (analogous to mandatory special management zones), for streams with 30% slope, but includes a 3 m no-harvest zone to be established within the inner streamside edge of the AOC. The buffer extent is similar to levels within other Canadian jurisdictions, and exceeds the special management zone width requirements

of voluntary forest management certification standards developed for both the United States and Canada. The prescriptiveness of streamside management options presented here has been updated from McDermott et al.'s (2009) original research.

Table 4. Average number of parameters and size classes for streamside riparian buffer zones by region (Table 2 from McDermott et al. 2009, with the *Ontario Stand and Site Guide* added).

	Average number of classification parameters	Average number of buffer size classes
North America[a]	3.2	5.5
US Pacific and Northwest	7.7	13
Western Europe	0.8	1.5
Asia	0.5	1.5
Eastern Europe	1	4
Latin America	2.3	6.7
Oceania	2.3	6.6
Asia	0.5	1.5
Africa	0.5	1
Ontario *Stand and Site Guide*[b]	3 (5)	5

[a]Canadian provinces included are British Columbia, Alberta, Quebec, and Ontario (provincial lands).
[b] In the *Stand and Site Guide*, the values are from 4.1.2 - Flowing waters: rivers and streams - specifically values from Table 4.1b. The value (5) for buffer size classes is from a slope based operational prescription for AOC standard, which has 4 slopes AOC values and one for MPS (moderate potential sensitivity). For average number of classification parameters, the value can be set to 3, because there are three sensitivity categories for streams, or it can be set to 5, as four sub-parameters (fish, fish habitat, catchment area, and distance from larger bodies of water) are used to determine buffer sensitivity, which together with slope is used to determine the management prescriptions, i.e. the buffer width (size of AOC)

Within Ontario, the degree of policy prescriptiveness varies considerably between forest certification schemes and the provincial *Stand and Site Guide*. All of the CSA, FSC and SFI standards included greater use of procedural measures, while the *Stand and Site Guide* consistently used mandatory substantive measures. The *Stand and Site Guide* was also the most site-specific, and provided the highest number of substantive regulations within an existing AOC prescription for multiple biodiversity values.

Variance in policy prescriptiveness may be attributed to the level of standard setting and geographic scale of the organization. That is, CSA and SFI standards are established at national (country) and North American levels, respectively, resulting in a systems-level focus and procedural capacity to realize sustainable forest management standards via planning efficiency and applicability across multiple Canadian jurisdictions. The FSC National Boreal Standard is tailored to a specific ecosystem type in Canada, across provinces, while Ontario guides work at a smaller geographical scale.

Several inductive hypotheses developed by McDermott et al. (2009) suggested a correlation between social-economic development and public perception and the prescriptiveness of standards, which were not assessed within this report, but have been resolved as having strong causal links in the Nordic-Baltic region (Ring et al. 2017).

4.6 COMPARISON OF POLICY APPROACHES

Differing approaches to address the impacts of biomass harvest have been developed in a number of wood pellet importing countries, including the European Union member states, such as United Kingdom, Denmark, The Netherlands, and Belgium (Stupak & Smith 201). Sustainability criteria for bioliquids placed in the European Union markets are included in the Renewable Energy

Directive (RED I) (EU 2009), which are linked to eligibility to subsidies. An adopted new directive (RED II) to succeed existing regulation after expiry in 2020 additionally includes sustainability criteria for solids (EC 2017). It will enter into force from 1 January 2021. Commitments for renewable energy use will be advanced under the RED II, as new criteria are introduced also for forest biomass and other wood industry sources (WPAC 2016). Apart from documenting a certain level of greenhouse gas emission savings, bioenergy feedstock eligible for subsidies must originate only in countries where national or sub-national laws exist, with monitoring and enforcement systems to ensure low risk that the wood is illegally harvested; forest regeneration takes place; areas of high conservation value, including wetlands and peatlands are protected; impacts of forest harvesting on soil quality and biodiversity are minimized; harvesting does not exceed the long-term forest production capacity (Article 29(6)); and accounting and maintenance of carbon stock and sinks levels in the forest (Article 29(7)). Operators (wood pellet producers) should apply a risk-based approach for compliance verification, which will be developed by the European Council. Following the current policy implementation, EU member states are also able to ratify additional sustainability obligations above and beyond RED II requirements for biomass fuels.

Biomass producing countries and regions rely on existing legislation, "traditional" forest certification (FSC 2019a, PEFC 2019) and new biomass certification systems, such as the Sustainable Biomass Partnership (SBP 2019) to show compliance with sustainability requirements of importing European countries. For this paper, Norway and Sweden were selected for comparison of sustainable forest management policy design due to similar vegetation zones (mainly boreal forest) and international sustainability commitments. These countries are different from Canada in being characterized by high levels of private and managed forest lands. In Norway 88% of the forest area is privately owned (NMAF 2007), and in Sweden 81% (KSLA 2015). Norway have a relatively low and Sweden a very high forest biomass harvesting and utilization for energy. Our report aims to understand how the *Ontario Stand and Site guide* and national SFM policy makeup compares globally, as exemplified by the four selected key requirements.

The Norwegian Forest Act (2005) is applicable to all forest management in Norway. The current national forest programme in Norway is referred to as the sum of policy activities, including the government supported Living Forest Project in 1995-1998 (Norwegian Government 2007, OECD 2011). The Living Forest Project resulted the Living Forest standard (1998), which was a national-level standard that was also the country's PEFC standard (Auld and Gulbrandsen 2015). The standard was formally suspended in 2010 owing to disputes on the Living Forests governing board (OECD 2011). Since then, the Norwegian government has developed a new forest strategy, which focuses on the contribution of the forest sector to value creation, employment and solving the challenges associated with climate change (Norwegian Government 2015). The Norwegian PEFC standard was revised 2013-2015, resulting in the *PEFC N 02 Norwegian PEFC Forest Standard* (PEFC Norway 2015). At present, about 61% of the forest area is certified to PEFC in Norway (PEFC 2019), and only about 3% to FSC (FSC 2019a).

The Swedish Forestry Act is also applicable to all forest management in Sweden (Swedish Forest Agency 2017), which has undergone several revisions since the first act was adopted in 1903. Revisions took place to adjust to reshaped policy goals, including forest restoration in the early times, production of raw materials for the forest industry after the Second World War, and finally various environmental goals following the Earth Summit in Rio in 1992 (Lindahl et al. 2017). *The Swedish Forest Act* is administered under the Swedish Forest Agency (SFA), the dominant authority on forestry and conservation issues, together with the Swedish Environmental Protection Agency (SEPA), that is tasked with management of natural reserves. Current natural resource regulations in Sweden are characterized as "management by objectives" and often paired with soft legislation due to a strong sense of sectoral responsibility and deregulation, with most of the requirements interpreted as minimum thresholds to meet policy objectives. The Swedish forest

governance system has thus changed significantly in recent decades, with a shift from public regulation to multi-level governance, of which forest certification is also part (Lindahl et al. 2017). Certification is also highly adopted, and at present, about 57% of the Swedish forest area is certified to PEFC (PEFC 2019), and about 45% to FSC (FSC 2019a). More than half these areas are double-certified. The SFA has developed specific guidelines and recommendations for forest biomass harvesting and wood ash recycling (Swedish Forest Agency 2008), to which for example the Swedish FSC forest management standard adheres (FSC Sweden 2010.

A comparison between the public policies with the highest possible level of detail, i.e. the *Ontario Stand and Site Guide*, Swedish recommendations for forest biomass harvests, and *the Norwegian Forest Act* shows that all three jurisdictions have relevant guidelines and best management practices relating to woody debris, biodiversity conservation, and soil quality. In the case of riparian buffer protection, regulations in Sweden and Norway require protection to ameliorate the impact on surrounding species, water and soil quality, and cultural values, but no buffer widths are provided in their forest acts or associated guidelines (Ring et al. 2017, Table 5). According to Ring et al. (2017), buffer widths in Norway are referenced to the PEFC standard, which requires a basic buffer zone width of 10-15 meters, but wider zones especially for rich deciduous, tall-herb, tall- fern and swamp woodland (25-30 meters), but also for swamp forest and dry vegetation around the waterways, while a narrower zone is allowed for single-layer pine forest and densely layered deciduous forest around the waterways.

By contrast, requirements for forest management certification schemes within each region (Table 6) are more alike. All three standards utilize a similar level of operational discretion. The Norwegian PEFC standard displays the most stringent riparian buffer thresholds, followed by the Canadian FSC National Boreal Standard. Both certification schemes utilized substantive requirements as opposed to the Swedish FSC, which applied mixed and procedural protections for riparian and retention requirements. Another difference is that buffer zones under the Swedish and Nordic certification systems are developed to buffer against nutrient run-off, in addition to other factors, which is a technique seldom employed in North America. All three standards also reference High Value Conservation Forest, or corresponding forests, and soil erosion as indicators for sustainable management. High Conservation Value Forest requirements were uniform, and conversion to plantations was prohibited by all three schemes. They also emphasize the necessity of planning, monitoring and mitigation actions to prevent degradation, and utilize comparable policy types to validate conformance with certification requirements.

Table 5. Comparison of Ontario, Norwegian and Swedish forestry policies with regard to riparian buffers, residual retention, skidding and High Conservation Value forests. The description of requirements for riparian buffers in Sweden is from Ring et al. (2017).

Protection	Ontario Stand and Site Guide (2010)	Norwegian Forest Act (2005)	Swedish Forestry Act (2017), including general advice and recommendations for biomass harvesting
Riparian buffers	• A protected area is required (area of concern, AOC), ranging from 30 m to 90 m depending sensitivity of the water body and on slope of banks for both rivers, ponds, lakes, and streams.	• "If the municipality finds it necessary to prevent major negative effects on the environmental values, including pollution of important water resources, the municipality may refuse forest owners permission to plant in treeless areas, to change tree species, to dig ditches, fertilize or use pesticides. The municipality may also lay down conditions in such cases."	• Riparian buffers with trees and shrubs must be left to protect species, water quality, etc., when managing forests. • When managing forests, harmful nutrient leaching and sediment transport to lakes and streams must be prevented and water quality preserved or improved. Use of pesticides, fuel or oils, must be done so that damage to the environment is prevented. • Damages from forest fertilization and off-road forest transportation must be prevented or limited, and site preparation and stump harvesting are prohibited in riparian buffers. • Felling residues should not be stored in the buffers.
Retention	• In clearcut systems, wildlife trees must retained at an average of ≥25 stems/ha, and an average of ≥10 large stems and a minimum of 5 large living trees per hectare.	• The Ministry may impose more stringent restrictions on forest management in forest areas of particular environmental value associated with biodiversity, landscape, outdoor recreation or cultural heritage than are otherwise authorized by the Act when forest management may result in major damage to or adverse effects on these values.	• When residues are harvested it is important that trees, shrubs and dead wood previously left for the natural and cultural environment are left and not damaged. • Forests with high natural values, such as some swamp forests and key biotopes, should be excluded from harvesting of residues if there is risk that natural values can be damaged. • Harvest residues should only include the most common tree species in the landscape. At least one fifth of the felling residues should be left on the cleacut, preferably in sun-exposed locations, with priorities to coarse dead wood (diameter > 10 cm), tops, coarse branches and dead wood from deciduous trees and tops of pines. • Avoid harvesting residues in sensitive biotopes and during periods when wildlife can be damaged.
Skidding	• Guidelines for road and water crossing construction	• The construction and repair of forest roads must be permitted by the municipality of operation, and demonstrate "consideration for important environmental values" • The Ministry may issue further regulations concerning planning, approval and building of forest roads and of other construction associated with forestry.	• Recommendations and guidelines for road construction transport in the terrain. • No roads construction in direct connection with lake shores, watercourses, sensitive biotopes, cultural relics and generally used paths. • Driving in the stand should take place with off-road motor vehicles, not trucks. • Technology, system and timing for removal of logging residues and ash recycling should be chosen so that driving does not involve the transport of sediment and organic material to watercourses or damage to cultural and ancient remains, and that mechanical damage to trees is limited.
High Conservation Value Forests	• Direction offered by the ESA and supplementary guidance for implementation.	• Regulations may be issued that forests shall be protected, when it "serves as protection for other forest or [against] natural damage", or in areas near mountains or ocean, where the forest is vulnerable. • Forests of environmental value may face more stringent restrictions on management, e.g. according to the Nature Conservation Act.	• Forest owners must describe how their management satisfies natural conservation and cultural heritage preservation interests. • Protective zones with trees and bush must be considered. • Protected forests managed under the Swedish Environmental Law and the Swedish Environmental Code (Swedish Protection Agency (2017).

Table 6. Comparison of the Canadian FSC National Boreal Standard (FSC Canada 1994), the Norwegian PEFC standard (PEFC Norway 2015) and the Swedish FSC standard (FSC Sweden 2010) certification standards with regard to riparian buffers, retention, skidding and High Conservation Value Forests (HCVF).

Protection	FSC National Boreal Standard	Norwegian PEFC	Swedish FSC
Riparian buffers	• Inner riparian reserves are a minimum width of 20 m from the treed edge of permanent water bodies. • Additional reserves for other values established for a minimum of 45 m.	• Buffers are listed under Requirement 24, Water Protection. • A minimum 10-15 buffer zone is to be developed but should be adjusted based on biotic conditions. • For rich, deciduous, tall-herb swamp woodland, a wider buffer zone of 25-30 m is prescribed • Cf. also Table 5	• Managers of major holdings shall demarcate any buffer zones required adjacent to habitats with specific biodiversity values.
Retention	• 10-50% in harvest operations based on level of expected post-disturbance residual compared to the pre-industrial condition (PIC). • Where intent for Principle 6 (environmental impact) is concerned, residual retention should be greater than 25%.	• Standing dead deciduous trees, large dead pine, natural high stumps of all tree species and fallen dead wood (low) more than five years old must generally be saved when felling. • Retention of 10 storm-resilient trees ha^{-1} when conduction rejuvenation felling. • It must be possible to identify retention trees, and generally they must remain in the forest when they die.	• Managers shall generally retain all snags, wind-throw and other threes that have been dead for more than 1 year.
Skidding and erosion	• Ground rules must be established to describe practices that avoid and minimize soil rutting, at a minimum, standard operating procedures addressing prompt regeneration of skid trails.	• Skidding requirements are listed under Requirement 4, Forest Roads. • "When planning and building forest roads, emphasis must be placed on outdoor recreation, environmental values".	• Written guidelines must be prepared and implemented to control erosion.
High conservation value forests	• Applicants must recognize and appropriately manage areas of High Conservation Value. • Conversion of HCVF to plantations is not allowed.	• High Conservation Value targets are not explicitly stated, but are covered through an analogous "special environmental values" requirements that include prescriptions for key habitats, areas of wetlands, cultural monuments and cultural environments, and other values.	• Managers shall identify HCVF (HCVF1-4) and management activities must maintain and enhance their defining attributes, including safeguards for endangered species. • Conversion of HCVF to plantations shall not occur.

Government forestry policy formulation in Sweden and Norway displayed a high level of variation and typically yielded lower prescriptiveness than the *Ontario Stand and Site Guide*, in part, due to the reliance on additional ordinances or voluntary measures to protect sustainability values. Norwegian and Swedish government policy mostly displayed mixed policy types, where only goals were set, but neither prescriptions on how to reach the goals nor strict enforcement systems for control that they are being achieved at the individual forest owner level. To some extent the legislation is designed to rely on certification standard to provide operational requirements for sustainable forest management, whereas the *Ontario Stand and Site Guide* contained a large number of mandated substantive policy requirements.

In Sweden and Norway, forest governance thus relies on multi-level approaches and mixed/elective of policy requirements. The institutional relationship is designed to achieve sustainable forest management goals on the ground through less prescriptive legislated requirements, enabling businesses to achieve the minimum threshold and pursue their own

innovate or suitable compliance strategies, e.g. through forest certification. National guidelines in these regions may therefore be interpreted as a "lighter handed approach", providing information on appropriate compliance strategies rather than de-facto regulatory standards themselves. Procedural government strategies found within the Swedish and Norwegian forestry acts also promote risk identification and management solutions developed by forestry managers, rather than designation by a central authority, which may be effective in situations where there are cost barriers to monitoring and multiple, complex sources of risk.

In Ontario, prescriptive standards are approached through codified and operationally prescriptive rules that articulate detailed performance measures and the underlying management objectives, which foster shared viewpoints between industry and the MNRF. One of the benefits of such policy design is to enable a high level of regulatory intervention by provincial authorities, and a greater propensity for compliance. However, due to the highly stringent nature of policy standards, management options for businesses may be limited and a greater administrative cost is incurred, as detailed operational guidance is required for successful implementation. The detailed guidance aims to ensure that participants are armed with adequate understanding of the compliance conditions. In addition, there is a need for the direct measure of the desired outcomes to keep the governance framework intact, which is achieved through self-reporting and ground-truthing of reported results by field visits.

While there are no inherent benefits to either policy designs, each policy application requires a prudent selection of a suitable level of prescriptiveness and level of guidance material. Mixed policy approaches may suffer from the use of minimum threshold guidelines which undermine regulatory performance if stakeholders recognize such "safe harbors" as the norms for compliance. By meeting the bare conditions for sustainable forest management, going above and beyond what is required, such as the implementation of best management practices are not incentivized and not pursued. On the other hand, there is an immense burden both in business responsibility and institutional cost in guidelines where each prescriptive standard must be set out in legislative terms, which may discourage new entrants to the industry and stymie alternative management methods. Both policy types, in their existing implementation, may generate high levels of legitimacy and normative support; multi-level regulation provides opportunities for interested stakeholders and industries to develop and enforce their own regulations, for example through certification standards, while the prescribed science-based, consultative and adaptive process used in provincial standards engenders trust and consensus in the Ontario framework.

For the purpose of the Canadian bioeconomy and possible future production of bioliquids, gaps are present within the existing governance framework compared to the requirements stipulated under RED I. The failure of the European Union to produce harmonized sustainable criteria for biofuels may be problematic for Canadian trade, as vagueness in basic terms may bar some exporters from eligibility. For example, the term "primary forest" (Article 17.3(a)) contradicts with the unique Canadian forestry environment characterized by significant natural disturbance and the sustainable harvest of stands derived from thousands of years of forest ecosystem development since glaciation. The classification of primary forest is also not used or collected for forest statistics by Canadian federal and provincial agencies, which generally distinguishes landscapes as either managed or unmanaged. Similarly, the requirement for "continuously forested" land (Article 17.4(b)) may bar Ontario pellets on the basis of clearcut harvesting operations, even if stands are naturally or artificially regenerated.

Benchmarking of national forest governance systems, as those of Ontario, Norway and Sweden, with RED II criteria have not been conducted yet. The outcome would depend on the interpretation and implementation of the criteria. Work is still ongoing to clarify these issues. Existing National systems in the United Kingdom and Denmark immediately accepts FSC and PEFC

certified material, while the Netherlands only accepts FSC certified material, or they accept national PEFC systems with standards that are comparable to FSC. SBP is an often used system for collection of all documentation for non-certified materials and data for calculation of greenhouse gas emission savings (SBP 2019). Regional risk assessments show that existing jurisdictional regulation and data can cover a range of requirements, but often not requirements related to biodiversity values (Stupak & Smith, 2018).

It is not clear to which extent forest management and land use, land use change and forestry (LULUCF) criteria can be met by existing systems, depending also on the exact rules for implementation, especially for countries that are not signatories to the Paris Agreement. Scholars have argued the applicability of terms and usefulness of sustainable forest management indicators such as carbon stock and sink accounting at stand levels and for periods shorter than a single rotation (e.g. Ter-Mikaekian et al. 2011). The assumption that all emissions and removals from managed lands result from human activities is also argued, as these can be confounded by the effects of natural disturbances (Kurz et al. 2018). The question is whether future rules under RED II LULUCF criteria will consider such complications.

While national carbon accounting for LULUCF reporting under the UNFCCC framework and the Kyoto Protocol exist at the national level, the lack of carbon monitoring within the Ontario provincial framework and prevailing forest certification schemes is also problematic. Both frameworks do not assess greenhouse gas emissions at the landscape level. Studies conducted by the Wood Pellet Association of Canada and the University of Toronto demonstrated that wood pellets under 20 percent moisture content would generate similar or less carbon dioxide per MMBTU than coal, and up to a 91% reduction in greenhouse gas emissions for 100% biomass usage in domestic coal generation power stations (Zhang et al. 2010). It is probable that existing exports meet criteria requirements through Life-Cycle Analysis (LCA) conducted by end users, but are likely to be based on incomplete or inaccurate data obtained through estimation. Differences between forest management standards and biomass environmental criteria corroborate findings by Gan & Cashore (2013), who discussed the increasing need for integration of bioenergy certification into existing certification products such as those certified by the SFI and FSC to play a transitional role in bridging trade barriers (see also van Dam et al. 2010).

5 Policy compliance and effectiveness on the ground

5.1 NATIONAL MONITORING

In addition to standards-setting, the assessment of progress towards sustainability goals and results on the ground in a transparent, consistent and verifiable manner is crucial in demonstrating Canadian commitment to national and international sustainability agreements, maintain its reputation across international markets, and to strengthen faith in the overall governance framework. Canada is party to a number of international conventions (see: Table 17.1, Mansoor et al. 2016), and non-binding processes that require national forest reporting on the state, condition and trends of forest resources, necessitating the development of functional resource inventories and standardized survey methods.

An array of federal and provincial monitoring programs is engaged to satisfy international forestry data requests. The National Forest Inventory (Canada's National Forest Inventory 2019), managed by the Canadian Forest Service and Natural Resources Canada, is responsible for all international reporting requirements and provides data estimating the rate, intensity, and extent of forest change over time. The system improves on prior inventory programs through the use of

permanent observational units on a national grid, rather than the periodic compilation of interagency surveys, which suffer from inoperable data types and varying data quality. The program applies a two-component monitoring program - a series of photo plots measure species composition, age, height, crown closure, volume, and forest-stand structure, while ground plots assess attributes for volume, growth, biomass and woody debris by diameter and decay class, percentage cover of shrubs, and soil. The information collected provides data for the reporting to the criteria and indicators under the Montreal Process, and provides input to the FAO Global Forest Resources Assessment (FRA) Reports (FAO 2019).

Other national projects have also targeted the need for historical, automated, geospatial datasets on Canadian forest cover, productivity, and carbon exchange. The Earth Observation for Sustainable Development of Forests (EOSD) (Wood et al. 2002) was developed in partnership with the Canadian Forest Service and The Canadian Space Agency to establish a land cover map using satellite data. EOSD products supply in-depth information regarding resource attributes, remote sensing and satellite imagery of phenological and surface characteristics. The spatial dataset and map generated by EOSD Landsat data covers over 80% of the country, comprising of 610 tiles at 25 meter of resolution, and provides information for biomass estimates, forest fragmentation and land cover classification, which contribute to national reporting obligations for the United Nations' Convention on Biological Diversity (UN CBD 2019). Remote sensing technologies for the measurement of biomass were also introduced under the BioSpace program in 2011, as a joint project between the Canadian Forest Service and Canadian Space Agency (NRCan 2019a). The satellite data tracks four landscape characteristics: topography, productivity, land cover, and disturbance.

National monitoring programs are supported by the development of a National Forest Information System (NFIS) (Canadian Council of Forest Ministers 2019), established in 2000, which provides an open information infrastructure for the dissemination and integration of forest resource data across different jurisdictional boundaries. Authoritative and current datasets from the NFIS are publicly accessible through an online web portal and is used internally by provincial ministries as a data warehousing solution.

Broad indicators are tracked through the State of Canada's Forests reports, an annual evaluation of national forest health, e.g., The State of Canada's Forests report 2018 (NRCan 2018). This report addresses a new thematic subject every year and compiles statistics on six sustainability criteria: total forested land base, sustainable timber harvest, impacts of disturbance, forest industry and economy, social-economic benefits, and changes to the forest industry.

5.2 PROVINCIAL MONITORING

Provincial monitoring and oversight are achieved through programs conducted at the forest management level. Monitoring programs in Ontario comprise a compliance component to substantiate self-reporting results from forest companies and conformance to provincial regulations, and a support program to identify the condition, state and quantify trends of Crown forest resources (e.g. for 2016, see OMNRF 2016).

A provincial forest inventory is maintained as Ontario's Forest Resource Inventory (FRI), which captures forest characteristics at the beginning of each new forest management plan (generally a period of 10 years) (OMNRF 2015). FRI production typically spans two years, and converges black and white and infrared imagery. The resulting data is delineated and spatially referenced with information on stand age, composition, species composition, stocking and values derived from the Forest Ecosystems Classification (FEC)(e.g., see Sims & Wickware 1984). Supplementary field data are collected by ground crews and awarded contractors under the permanent forest inventory

photo plots, inventory ground plots, sampling calibration plots, and post production assessment plots to enhance the accuracy of imagery interpretation.

Many of the monitoring programs have been backed by a legal mandate under the Class Environmental Assessment provisions (see Table 3). Table 7 lists additional monitoring responsibilities enshrined by the *MNR-71 class environmental assessment declaration* (OMNRF 1994), which are mandatory on all forests within Ontario's AOU, as a set of "Terms and Conditions" to guarantee the sustainability of forest management. Although the new revision to the declaration, MNR-75 (OMNRF 2014d), in 2015 has removed the explicit requirement for the maintenance of listed monitoring activities, program requirements have since been incorporated as standards with the management guides for forest management, and as a result, are still being maintained, and covers not only productive forested stands, but also non-productive and non-forested lands.

Table 7. Monitoring required by Ontario *MNR-71 class environmental assessment declaration* (OMNRF 1994).

Monitoring program	Legal requirement	Description of monitoring activities:
Wildlife assessment program	Environmental Assessment (EA) approval condition 30	Monitors the population, status and trends for representative wildlife and develops technique for their detection. Information is collected from permanent sample plots, other inventory programs and from external partners.
Forest Resource Inventory (FRI)	EA approval condition 9	The FRI program collects information on the composition of the forest for all land within the Area of Undertaking. Information collected includes species composition, average stand age and height, stocking, site class, and ecological classification.
Guideline effectiveness monitoring (GEM)	EA approval condition 31	The GEM develops testing methodologies, provides feedback and advice, and analyzes results for other monitoring programs.
Ecological land classification program (ELC)	EA Approval condition 41	The ELC program describes, identifies, and monitors ecosystems within Ontario and ensures a consistent method of ecosystem interpretation and inventory for a wide range of other authorities and municipalities within Ontario.
Growth and Yield program	EA Approval condition 42	Gathers growth and yield information on major tree species from historical plots, permanent sample plot, and partnership projects.
Genetics monitoring	Conducted informally	Genetics monitoring is conducted to maintain and improve forest productivity and conserve genetic diversity.
Socioeconomic Monitoring	EA Approval condition 45	Socioeconomic monitoring measures the economic, social, and demographic values for forest industries in Ontario and other jurisdictions.
Forest values	EA Approval condition 40	Forest Values Data Collection is performed by forest management entities and stipulated under the forest management planning process. Species at risk, road access, cottages and other values data are collected by field personnel and reported to the Ministry.

Verified compliance with guidelines and planning documents (see 3.1) are implemented through four monitoring programs: forest operations compliance, independent forest audits, silvicultural effectiveness monitoring and forest health monitoring. Compliance programs are conducted by "Certified compliance inspectors", who must undergo training by the Ontario Ministry of Natural Resources and Forestry, including annual workshops, maintenance of operation manuals, and shadowing with Crown licensees and operators. Forest renewal, a requirement of the provincial planning process, is coordinated through the OMNRF during the formation of a forest management plan and include on-the ground surveys for regeneration surveys or helicopter surveillance for

free-to-grow sites. All audits are performed in accordance with the Forest Compliance Handbook (2014) and Forest Compliance Inspection Program (OMNRF 2019d), which provides direction and rules for understanding forest compliance and how it is achieved. Table 8 summarizes the timeframe, content, and forms of monitoring and audits.

Table 8. Timeframe, content, and forms of monitoring and audits required in Ontario.

Frequency:	Annually	Every 5 years	On-going basis	Every 5-7 years
Policy name and legal requirement	Forest Operations Inspections (Compliance)	Silvicultural Effectiveness Monitoring	Forest Health	Independent Forest Audit
Monitoring authority	MNRF, Forest management entities	MNRF	MNRF and CFS	Conducted by auditors selected by the Forestry Futures Trust[a] committee.
Audit content	• Direction provided by the Forest Compliance Handbook • Forest management companies carry out self-monitoring, training and education and product reports sent to the MNRF which archives and reviews inspection documents through the Forest Operations Information Program, a web-based database. • Additional audits evaluate conformance with standards, guidelines and rules. • Evaluates four primary areas: Assessment of regeneration success, roads and water crossings, fire prevention and preparedness, and comparison of proposed operations to the long-term management direction. • [a] Four areas taken from FMPM 2009 Manual, p. B-36	• Assess the results and effectiveness of forest regeneration • Primarily evaluates three activities: regeneration by year, state of regeneration and regenerated forest, and comparison of actual and target regeneration rates.	• Monitors disturbance (i.e. weather, diseases, and insects) on forest health. • Determines impact on forest values and provides predictions for future disturbance.	• Audits review documents, conduct interviews, and visit certain sites to appraise compliance with policy direction, standards, planned results, and conditions for SFL. • Concerns are presented to the forest company/ MNRF. • Findings and recommendation are reported to the legislature. • Licensees and MNRF must create action plans on how to combat non-compliance and audit recommendations. • Licensees and MNRF prepare a status report to document progress.

[a] http://www.forestryfutures.ca/

Provincial monitoring programs are also linked to a hierarchical system of criteria and indicators developed by the Ontario Ministry of Natural Resources and Forestry to reflect provincial sustainable forest management objectives, public perception and long-term results for Ontario's forests (Table 9). Indicator fulfillment are evaluated every 5 years through a comprehensive review of gathered environmental information and resource inventory surveys and presented published in the *State of Ontario's Natural Resources Forests reports* (see archives, OMNRF 2019e). The evaluation reviews the state of current indicator performance, trends and quality of data available associated with each criterion.

Table 9. System of criteria and indicators developed by the Ontario Ministry of Natural Resources and Forestry to reflect provincial sustainable forest management objectives, public perception and long-term results for Ontario's forests.

Criteria	Number of indicators
1. Conserving biological diversity	9
2. Monitoring forest productivity and resilience	10
3. Protecting forest productivity and resilience	4
4. Monitoring forest contributions to global ecological cycles	10
5. Providing economic and social benefits from forests	15
6. Accepting Ontario's social responsibilities for sustainable forest development	5

Biodiversity is also a major theme for Ontario and monitored extensively (ONMRF 2014b), although not on a province-wide scale. A set of biodiversity criteria and indicators have been established in parallel and inform provincial programs for climate change, wildlife, and conservation activities. However, the OMNRF supports several point-in-time indicators such as the North Plot Reference Database and Southern Ontario Land Resources Information System (SOLRIS) (Furrer et al. 2014), which could be used to assess changes in land conditions over time. Several partner agencies also conduct periodic surveys, such as the Ontario Biodiversity Council Awareness Survey every 2 years (Ontario Biodiversity Council 2016), the Ontario Public Service (OPS) Biodiversity Network survey of Biodiversity Program every 5 years (OMNRF 2019f), and Ontario Invasive Plant Council Survey of Invasive Plant Species (see resources: Ontario Invasive Species Council 2019).

5.3 FOREST CERTIFICATION MONITORING

Forest certification systems also employ enforcement and monitoring mechanisms to identify fulfillment of certification requirements. Similarities exist between provincial and certification standards in that forest management compliance monitoring is conducted at the forest management unit level, guided by principles of sustainable forest management; and contribute to the increased effectiveness of management systems. On the ground compliance is assessed through independent audits conducted by third-party inspection by assurance companies that identify non-compliance, areas of improvement, and provide recommendations for best management. Monitoring requirements under the selected certification schemes differ in terms of intent, periodicity, and scope, as certain activities are used to demonstrate compliance (as an indicator), rather than as principle or independent objectives specifically designed to support results on the ground.

For the purposes of this report, only the standards' requirements for monitoring (as a principle or independent objective) are listed (Table 10), as such measures are explicitly designed to promote sustainable results on the ground, rather than conformance to standard performance and system requirements (as described above in Tables 5 and 6).

Table 10. Monitoring requirements of CSA, FSC and SFI certification standards.

Certification Scheme	Conditions assessed
CSA	SFM system requirements: 7.5.1. Monitoring and Measurement The organization shall: a) Establish and maintain procedures to monitor on a regular basis towards conformance with SFM requirements in the defined forest area. b) Record performance and monitor indicators for comparison against targets/ forecasts, and Periodically assess the quality and meaningfulness of targets, forecasts, and non-core indicators where applicable.
FSC	Principle 8 Monitoring and Assessment: monitoring shall be conducted appropriate to the scale and intensity of forest management to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts. Criterion 8.2: Forest management shall include the research and data collection needed to monitor, at a minimum, the following indicators: a) Yield of all forest products harvested b) Growth rates, regeneration and condition of the forest

	c) Composition and observed changes in flora and fauna d) Environmental and social impacts of harvesting and other operations e) Costs, productivity and efficiency of forest management Additional monitoring requirements as indicators for other principles.
SFI	Objective 15- Management Review and Continual Improvement: To promote continual improvement in the practice of sustainable forestry by conducting a management review and monitoring performance. Performance Measure 2.2 - Indicator: monitoring of water quality or safeguards to ensure proper equipment use and protection of streams, lakes and other water bodies Performance Measure 3.1 - Indicator: Monitoring of overall best management practices implementation Performance Measure 7.1 - Indicator: Program or monitoring system to ensure efficient utilization of harvest residue and fiber resources.

Monitoring is described under all three certification systems as an instrument to deliver credible information for stakeholders, and to promote continual improvement with regards to SFM. Even though the record of yield, growth and environmental indicators overlap pre-requisite conditions for forest management planning in Ontario, the FSC and SFI are unique in that there are requirements for economic monitoring of forestry performance. Additionally, SFI standards prescribe the documentation of best management processes, which has been proposed as a cost-effective method for assessing SFM on multiple sites (Smith et al. 1999).

Independent audits for criteria and indicators may have wider implications in addition to market access. Bass and Simula's (1999, cf. Rametsteiner & Simula 2003) research on typology of certification identify several additive services including verification of forest management requirements, legal compliance, and certification of carbon sequestration and other environmental services. Since the early 2000s, certification systems have expanded to include provisions for wood pellet energy (SBP 2019) and fiber sourcing (SFI 2015b); lifecycle assessment along the supply chain including calculation of greenhouse gas emissions, land use change and social welfare requirements in line with the requirements of the EU 2009 Renewable Energy Directive (EU 2009) are yet to be developed. The broad nature of certification standards enables the surveillance of other sustainability measures such as labor relations, occupation safety and health, indigenous rights, employment, etc. These elements of sustainability have received increasing recognition within the fields of international governance and are seen as an integral component of sustainable forest management.

5.4 ROLE OF FORESTRY RESEARCH AND GUIDELINE REVISION

Ontario improves upon its forest stewardship through adaptive management (AM), a formal system of iterative policy setting and learning to improve implementation and long-term management outcomes (OMNRF 2010, Fig. 7.1a, page 163). By utilizing existing policy and on-the-ground activities as a source of learning, subsequent improvements and actions may be developed, reducing the uncertainty associated with new or adjusted activities and management alternatives (OMNRF 2010). In complex production systems, such as forest biomass production and harvest systems, ecological impacts occur at integrated, multiscale and long-term dimensions, creating a need for systematic update and revision to match the dynamic nature of landscape change and management goals and to adapt practice and standards with acquisition of new knowledge.

As part of the *Environmental Class Declaration MNR-75* (OMNRF 2014d), forest management guidelines must also undergo regular revision, at least once every 10 years. Guides are reviewed by forest researchers, the forestry sector and the public; recommendations are subject to technical review and oversight by the Provincial Forest Technical Committee (PTFC) (OMNRF 2019g) comprised of technical experts from the forestry industry, academia, aboriginal groups and environmental organizations prior to final publication. Previous processes including forestry management plans, Forest Operations Information Program (FOIP) reports, issues identified from stakeholders, auditors, and ministry staff are taken into consideration and posted for comment on the Environmental Registry (Environmental Registry of Ontario 2019a), a platform for individuals to comment on environmental proposals. Areas for management associated with high uncertainty are designated high priority targets for future testing through the province's effectiveness monitoring program under the guidance of the PFTC. Changes, updates and revisions to forest policy are also an indicator of Ontario's Forest Indicators, listed under the Criterion "Enhancing the framework for sustainable forest management". The indicator monitors the changes to all legislation applicable for provincial forestry and information for other programs or initiatives related to sustainable forest management.

The Ontario process-oriented approach is unique in that revisions are a legally mandated process (Puddister et al. 2011). Adaptive management promotes a stepwise and cautionary approach to understanding the long-term consequences of forest management, and emphasizes continual improvement through the use of new scientific information, experiential learning, and response to social demands for change.

A functional premise of adaptive management (e.g. Fig. 7.1a in OMNRF 2010) is enhanced information flow. In relation to forest bioenergy, a number of biomass information programs have been spearheaded by non-profit and research groups such as FPInnovations, and the Biomass North Development Center. A national workshop, titled the *Scientific Foundation for Sustainable Forest Biomass Harvesting* (Titus et al. 2010), was convened in 2008 to develop practical understanding in the policy, regulations and research pertaining to biomass harvest, with emphasis on seven bioeconomy research areas: site productivity, biodiversity, sustainability of supply, socio-economics, tenure, technology, and climate change. Such workshops promote collaboration and sharing of multi-disciplinary perspectives among government, industry, and academia.

Two Ontario forest research centers also conduct research directed at understanding forest management. The Center for Northern Forest Ecosystem Research in Thunder Bay (Government of Ontario 2019) is responsible for studying the effect of management guidelines, social implications for forestry, and impacts of biomass utilization on growth and productivity in the Boreal, while the Ontario Forest Research Institute (Government of Ontario, 2019) primarily investigates the function and efficiency of models on forest carbon cycling, disturbance, and forest diseases and insects. The Center of Research and Innovation in the Bio-Economy (CRIBE 2019) also received a $25 million investment to pursue research into new products and conversion pathways for biofiber. Such research enhances the understanding of logistical and economic feasibility of biomass by exploring new methods of harvest, renewal, and biomass use, aiding the development of sustainable of biomass harvesting practices and sustainable supply.

An example of adaptive management in practice can be seen in the evolution of full tree logging direction in Ontario. Prior to 2015, forest management guides limited full tree logging on very shallow soils (OMNR 1997). This direction was a conservative response to the limited information regarding the effect of nutrient removals on long-term site productivity. In recognition of the knowledge gap, the Canadian Forest Service and the Ontario Ministry of Natural Resources (OMNR, now OMNRF) jointly established a series of biomass removal trials during the years of

1993-1995 (Tenhagen et al. 1996, Morris and Duckert 1999, Duckert and Morris 2001). The design, establishment, and monitoring of these research installations was a legal requirement described in *Declaration Order MNR-75* (under Term & Condition 61: Forest Management Planning Direction, includes T&C 50: Full-tree Harvest and Full-tree Chipping Studies) (OMNRF 2014d). Trial sites specifically targeted those soil types (i.e., shallow to bedrock and infertile sands) deemed most sensitive to increased nutrient removals. The resulting installations now form an integral part of the North American Long Term Site Productivity (LTSP) network (Powers 2006), with data contributing to broad LTSP synthesis efforts examining early tree growth response to full tree harvesting (Fleming et al. 2006, Ponder et al. 2012), as well as to regional species-specific growth responses (black spruce: Morris et al. 2014, jack pine: Fleming et al. 2014). These emerging results (e.g. Morris et al. 2005), combined with other regional monitoring efforts (e.g. Morris et al. 2016), and complimentary information from the broader LTSP network (Powers 2006), were eventually used as evidence to support a review and revision of the full tree logging direction. A 12-person Advisory Team (OMNR 2015) concluded that full tree logging was unlikely to have a long-term impact on soil nutrients for typical rotation lengths in Ontario, and therefore the restriction could be removed. This preliminary conclusion was then deliberated by the Provincial Forest Technical Committee (PFTC) before drafting text for public consultation (EBR registry # 012-0985) and eventual approval (OMNR 2015). Even if this restriction has now been relieved, continued monitoring takes place on these long-term trials. Hence, they represent "effectiveness" monitoring of the guideline recommendations.

Research under the MNRF and NRCan-CFS has also been directed to understand the long-term effects of biomass harvest, and improvements to the provincial forest resource inventory to provide accurate estimates on wood supply (including biofiber). The Sustainable Forest Biomass Harvesting Research (CFS 2016) was initiated in the Great Lakes - St. Lawrence region in 2004, on three to four sites in Algoma Forest, Nissiping, Haliburton and Petawawa. It aims to enhance the understanding of soil, vegetation, understory growth, and amount of coarse and fine woody debris under a shelterwood and intensive biomass utilization treatment including removal of tops and branches. Pre- and post-harvest data are gathered every 5 years, and the study is expected to continue into perpetuity so long as there is available funding (pers. comm. Fera 2017).

A biomass harvest trial in second generation growth after pristine forest in jack pine was also been established in 2010-11 near Chapleau, Ontario ("The Island Lake Biomass Harvest Research and Demonstration Area"; Kwiaton et al. 2014). This project is a collaborative initiative that includes NRCan-CFS and OMNRF, as well as industry (RYAM, formerly Tembec Forest Products, Ontario Power Generation), First Nations (Northeast Superior Chiefs Forum), local forest-based communities (Northeast Superior Forest Community), and a number of academic institutions (e.g., Université de Quebec à Montréal, Laurentian University, Queen's University, Western University). Beyond evaluating soil properties and site productivity effects, the research team is using a multi-taxa assessment approach to evaluate the effects on biodiversity (Boisvert-Marsh et al. 2016).

Several permanent sample plots (PSPs) and Permanent Growth Plots (PGPs) in Ontario are maintained by the Ministry of Natural Resources and Forestry, which have been supported by the Boreal Forest Science Co-op (BFSC 2019). The plots serve the purpose of identifying growth-yield projections under AOC prescriptions and changing climate, and routinely provide insights into stand dynamics, mortality, and regeneration models used by the forest management planning process and calibration of national carbon/climate models (Ministry of Forests, Lands, and Natural Resource Operations 2010).

6 Supply chain control and assurance

6.1 THE CHAIN OF CUSTODY

A major sustainability challenge in biofuel deployment is the management of sustainability documentation and risk mitigation through downstream supply chains. This often lies beyond the purview of provincial government regulation and is often obscured through complex supply chain networks and trade flows across international borders (see, for example, Stupak & Smith 2018). Weak supply chain governance contributes imports of timber from deforestation and lands with poor forest management, which again undermines international confidence in claims about the sustainable sourcing of forest fiber, particularly for countries with weak governance capacity, high levels of corruption and trade fraud. It results in increased reputational risk, also for organizations that maintain high levels of documented sustainability.

Chain of custody (CoC) certificates are voluntary instruments that track sustainability documentation associated with certified wood products from the origin of the raw material, through processing and transport to final use. It involves implementing of track and trace and handling procedures to ascertain the certificates and prevent the addition of undesirable or illegal wood sources to the certified supply chains. In the context of international biomass and wood products trade, provenance and verification of origin are core obligations of the European Union Timber Regulation (EUTR) (EU 2010), which requires implementation of a due diligence system before wood is placed in European markets. Companies that market wood (through selling, trading, or production) must meet EUTR requirements to produce information, at minimum, on the timber products sold, country of origin, quantity, and the name of address of supplier and buyer, and assess the risk that the products marketed might be associated with illegal activities. Companies further down the supply chain must also keep sufficient records on the customers and may be fined if records are missing or not available for at least five years. Wood products from reclaimed sources (i.e. tertiary sources), are exempt, however, and would not require due diligence to be exercised.

The flow of Ontario biomass feedstock products must pass through multi-layered governance mechanisms across the entire supply chain (Figure 4). For large, integrated forest operations, where there is vertical movement of feedstocks along a single-stringed supply chain, there is little difficulty in maintaining or accessing the information required for risk assessment. However, firms and wood products production facilities using certified and un-certified sources from several landowners and geographical origins will face greater supply chain uncertainty and risks. Chain of custody instruments are designed to account for wood flows along the supply chain and simplify documentation transfers across different jurisdictions, e.g. for wood pellet trade, by managing sustainability claims from point of origin to purchasing customers requiring such documentation.

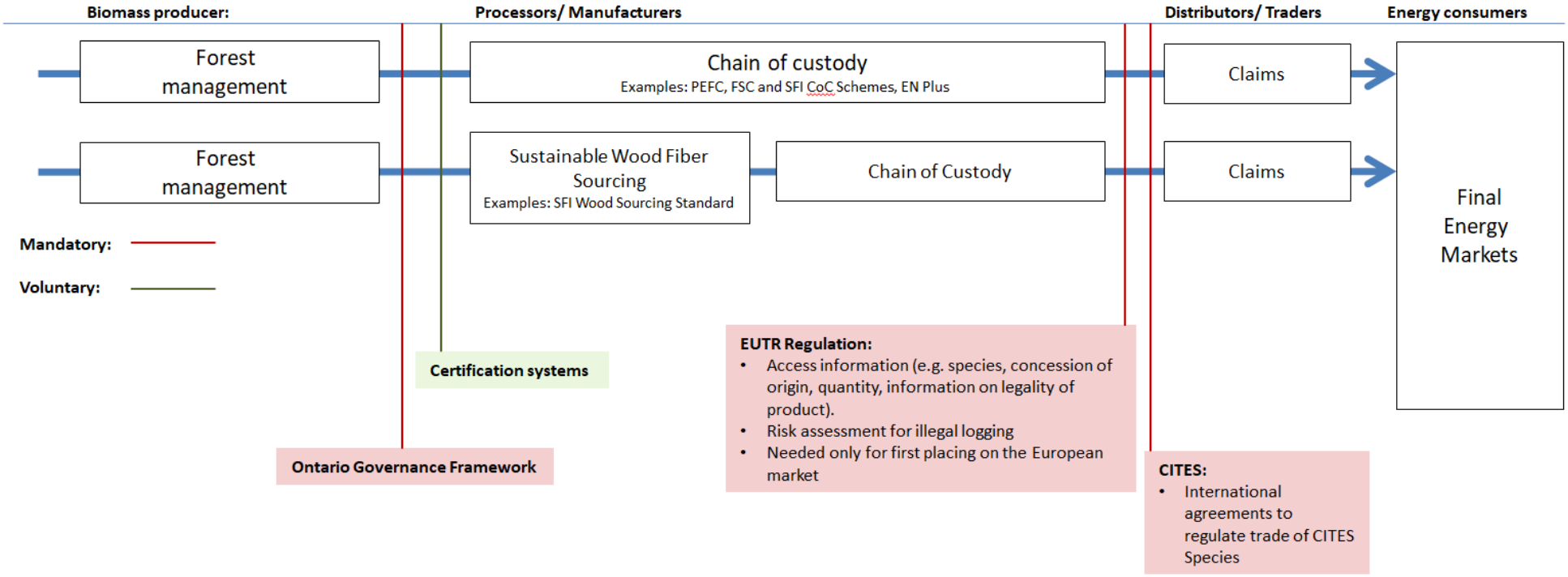

Figure 4. Examples of domestic and international sustainability governance through a forest bioenergy supply chain from Ontario Crown forest biomass producers to European energy consumers (after Kittler et al. 2012).

CoC certification standards are available in all three certification bodies analyzed in this report. In the SFI system, chain of custody is listed as an independent component of the 2015-2019 standards (SFI 2015c), in addition to Forest Management and Wood Fiber Sourcing standards. CoC standards exist as standalone certificate systems in the PEFC (PEFC 2015) and FSC (FSC 2016a) systems. The SFI system also uses the PEFC CoC standard. Verification audits for all three chain of custody standards are also performed by independent, contracted third-party certification bodies.

6.2 UNACCEPTABLE SOURCES

The definition of sources that are not acceptable for mixing with certified wood is fundamental to risk assessment. Sources with low risk of being unacceptable are called controlled wood in the FSC system and controlled sources in the PEFC system. The FSC has developed five categories of unacceptable material (FSC 2016b): illegally harvested wood, wood harvested in violation of traditional and human rights, wood harvested in forests in which high conservation values (HCVs) are threatened by management activities, wood harvested in forests being converted to plantations or non-forest use, and wood from forests in which genetically modified trees are planted. These criteria are covered to varying extent by the PEFC Chain of Custody standard (PEFC 2015) and the SFI Fiber Sourcing standard (SFI 2015b) (Table 11). All three standards rely on self-declaration of material categories and require companies to conduct risk assessments based on various types of information available about the country of origin. Any identified risks must be mitigated.

Table 11. Comparison of definitions of unacceptable sources of wood under FSC (FSC 2016a, FSC 2016b), SFI (2015c) and PEFC (2015) chain of custody certification standards.

FSC CoC and CW Standards	SFI 2015-2019 CoC	PEFC ST2002:2013	Summary
5 controlled wood categories: • Illegally harvested wood • Wood harvested in violation of traditional and human rights • Wood from forests in which high value conservation values are threatened by management activities • Wood from forests being converted to plantations and non-forest use • Wood from forests in which genetically modified trees are planted	3 controversial sources categories: • Forest-based products not in compliance with applicable state, provincial or federal laws, such as CITES requirements, labor regulations, and legally required management of areas with designated high environmental and cultural values • Forest-based products from illegal logging • Forest-based products from areas without effective social laws	Controversial sources are listed as: • Not complying with local, national or international legislation, including: requirements of CITES, management of areas with designated high environmental, and health and labor of workers. • Not complying with legislation of the country of harvest relating to trade or customs • Utilising genetically modified forest based organisms • Converting forest to other vegetation type including plantations	The FSC Controlled Wood Criteria are covered to varying extent by the PEFC and SFI

6.3 VOLUME CONTROLS

Volume controls ensure that matching volumes of certified material are shipped and received between linkages in the supply chain, providing transparency and accountability for material flows across the chain, especially when this involves mixing with controlled wood or controlled sources. In the absence of volume reconciliation tools there is the possibility of illegal wood entry through an accounting error or fraud between the total volume of certified and controlled wood sold and received. Even if CoC audits are performed for all companies in the supply chain, the absence of a unified material accounting record would prevent audits from determining the actual material flows, and non-certified or controlled wood may be added at either point. Entry of illegal materials

into certified supply chains destroys confidence in the sustainability claims of certification, and loss of customers trust in the label.

Another type of risk has been identified, as companies may continue to sell wood labelled as certified despite loss of certification status through expiry or suspension. As companies may only check the certification status of their trading partners prior to an audit or at infrequent, periodic intervals, non-certified wood may be incorporated unknowingly into the final product. Auditors have no visibility over wood flows until the time of audit, which masks the discrepancy. Table 12 summarizes the approaches to control of volumes by the different certification systems.

Table 12. Volume control procedures required by the FSC (FSC 2016a, FSC 2016b), SFI (2015c) and PEFC (2015) chain of custody certification standards

FSC CoC and CW Standard	SFI 2015-2019 CoC	PEFC ST2002:2013	Summary:
Applicants must maintain a material accounting record including inputs received, outputs, suppliers, buyers, and claim period. The organization shall prepare a report covering one period before the previous reporting period to demonstrate that the output products sold with FSC claims correspond to the inputs, existing inventory, and associated output claims.	The organization must maintain records for both incoming and outgoing material including the quantity of delivery, supplier/ organization identification, claim period, organization identification, chain of custody number, and quantity delivered.	The organization must maintain and produce documents for delivery (incoming) and sold products, including identification of organization, product and quantity delivered, delivery period, and formal claim on the material category.	All three methods utilize similar methods of volume reconciliation. Volume credit matching is the primary mechanism to accounting fraud, although the FSC requires a volume report, which may simplify the identification of invoice origination errors.
Controls systems used: • Transfer system (physical segregation from ineligible materials) • Percentage (mass balance system, giving the proportion of claim-contributing inputs over a specified claim period) • Credit system (mass balance system, giving quantity of claim-contributing inputs and the applicable product group conversion factor(s).	Controls systems used: • Physical separate method • Average percentage method, based on calculated certification percentage for all the products covered by the product group • Volume credit method, based on calculated certification percentage and volume of output products, or, based on input material and input/output ratio.	Controls systems used: • Physical separate method • Average percentage method, based on calculated certification percentage for all the products covered by the product group • Volume credit method, based on calculated certification percentage and volume of output products, or, based on input material and input/output ratio.	SFI and PEFC use the exact same systems, while FSC uses a similar system, except that the credit system is based on conversion factors rather than certification percentage and volume of output

Certification standards thus address volume controls indirectly, and only evaluate the procedures, strategies and plans established by the producer, for example through the documentation of products sold and received. Basic control systems use of percentage or volume credits, which are used as a means for mass balance to ensure that the proportion of certified and non-certified material in products composed of mixed inputs are evaluated and maintained. All three certification standards possess requirements to ensure that the percentage and volume credits do

not exceed the total claim. Such systems only apply to products with mixed and credit labels, sometimes with minimum thresholds for certified content.

New initiatives have begun to control certified volume flows more effectively than paper trains, such as FSC's voluntary Excel formatting tool Falcon for easy verification of transaction. Falcon is locally hosted within the company, but FSC aims to pilot a blockchain solution in order to strengthening the integrity of FSC claims (FSC 2019b). A previous attempt to strengthening the integrity of the claims, the Online Claims Platform, was less successful, and it currently is being phased out. The Internet solution ideally includes information on e.g. species, volume, price and conversion factor so that this is tracked throughout the supply chain. Once the trading companies have confirmed the order information, the transaction attributes are stored online, providing a mechanism for volume control audits across certificate holders.

6.4 ASSURANCE METHODS

Assurance methods relate to the quality of audits and how certification requirements are implemented and verified (Marx 2013). Assessments of conformity for certification processes are vital as it provides end users with assurance that the certification process is conducted in a uniform manner.

SFI, PEFC and FSC all use third-party auditing which is generally considered to be more stringent then second or first party audits, due to the formal independence between certification scheme, the certifying body and the certified body. Requirements for third party certifying bodies, the so-called accreditation system contribute to certification assurance (Table 13).

Moreover, the use of field visits ameliorates concerns over for example desk audit procedures, which may lead to weaker identification of non-compliance (O'Rourke 2002). However, neither SFI, PEFC or FSC hold public standards which explains their specific auditing requirements in this regard.

Table 13. Third-party accreditation requirements of FSC, PEFC and SFI certification systems.

FSC Requirement	PEFC ST2002:2013	SFI Requirement
FSC product management requirement: Certification bodies under FSC shall be accredited based on ISO/IEC 17065 and additional requirements are specified in a number of FSC Accreditation Standards.	FSC management system requirement: ISO requirements are listed under the PEFC ST 2002:2013 documentation, Annex 8: Minimum management system requirements Conformity assessments are considered as part of the product certification and shall follow ISO/IEC 17065	SFI product management requirement: SFI criteria for accreditation are listed under Appendix 3 and list assessment based on ISO/IEC 17065:2012 as a requirement
FSC accreditation standard: Requirements are found in FSC-STD-40-004 V3-0 Annex C Accreditation Service International (ASI), the FSC's accreditation arm, operates on the ISO 17011 standard	PEFC Accreditation standard: Accreditation is carried out in accordance with ISO 17065 (2016) or 17011 (PEFC 2007).	SFI accreditation standard: The SFI standard is verified by an independent organization (third party) following ISO 17065 accreditation. The three auditing bodies used by the SFI: the American National Standards (ANSI), ANSI-ASQ National Accreditation board and Standards Council of Canada are all members of the International Accreditation Forum and conform to the ISO 17011 Accreditation standard.

7 Strengths and unresolved issues

7.1 STRENGTH OF THE POLICY DESIGN

The effectiveness of guidelines are maximized when there is application of best available science, continual learning to accommodate incomplete information and uncertainty, extensive stakeholder engagement, and dissemination of knowledge to inform policy-makers, stakeholders, and ensure accountability and transparency in the progression towards achieving sustainable goals. Regulatory designs that incorporate such elements often benefit from normative support (Mansoor et al. 2016), enhanced stakeholder engagement, and reduction in policy and business uncertainties.

Within the Ontario forest policy framework, formal commitment to adaptive management provides a mechanism to enable policy to periodically be updated by new knowledge, and (hopefully) reduce environmental risk over time. The commitment to adaptive management complements the use of relatively prescriptive policy and ensures that regulation is not only updated regularly but reflects the current values of government, NGOs and the general public. Continual improvement mandated under the *Crown Forest Sustainability Act*, also establishes the legitimacy of the guidelines through their development process. It provides elements of a precautionary approach to mitigate risks and potential harms from new or exacerbated stresses on forests from abiotic and biotic sources. The commitment to continuous policy improvement provides an opportunity to review regulatory effectiveness though compliance and effectiveness monitoring, which establishes reform as a systematic and permanent process. An open, consultative process through recognition of the public, technical committees, and industry views also generates opportunity for reaching consensus and improves the possibility of reaching a shared understanding of governance objectives and desired outcomes amongst stakeholders.

7.2 ECONOMIC OPPORTUNITIES AND SPECIES PROTECTION

Many of the contemporary challenges facing biomass harvest are linked to policy implementation and the interaction between the different policy and governance priorities. In Ontario, the *Endangered Species Act* (ESA) was passed in 2007 with the intent of providing a baseline protection for species at risk (SAR) within the region.

The ESA functions through regulations designed to identify, protect and promote the recovery of species at risk. One of the main legislative mechanisms of the policy is the overall benefit requirement, which states that permits for natural resource management (and other activities) operating in areas linked to SAR values must demonstrate their plans and actions provide an overall benefit for the species beyond minimizing adverse impacts. Habitat regulation (ESA, subsection 10-1; Table 2) also prohibits the destruction and damage to habitats defined as the "impairment" and "elimination" of ecosystem function and species life processes within habitats.

The regulatory ability of the Act was amended and weakened through the *Ontario Regulation 242/08*, a 5-year exemption for multiple industries. However, exemptions for Crown forests and the forest sector expired in July 2018. Current operations within species at risk habitat follow the regulations as stipulated in the Forest Management Plan, but companies must consult with the MRNF for additional guidance and notify provincial agencies of any additional changes to habitat conditions and observed threatened species.

A new policy solution, the ESA-CFSA integration project is in place to streamline existing direction and simplify the regulatory approach for SAR, particularly to fill gaps in policy implementation (Environmental Registry of Ontario 2019b). Criticisms revolve mainly around the lack of

application of sound science and over-reliance on the precautionary principle for restrictive AOC direction, with habitat prescriptions based on "little or no scientific evidence or data", leading to the over-provisioning of productive land base away from the forest industry and thereby limiting economic opportunities for an already diminished sector. Policy overlap is another problem as the mandatory protection of species at risk are already a component of forest management planning under the CFSA "for nearly 20 years" (Nelson 2013, Serravalle 2017), and guidelines for specific species have been routinely published by the provincial government (OMNRF 2015). Integrated, efficient and transparent frameworks for governance are therefore vital, and robust science must be used to guarantee that policy solutions are acceptable to stakeholder groups.

7.3 MONITORING GAPS

Despite the existence of an extensive monitoring program, policy setting may also benefit from increased "validation monitoring" (sensu Smith et al. 1999). Three broad categories of monitoring may be pursued, notably implementation, effectiveness, and validation monitoring, in ascending cost and difficulty. Implementation and effectiveness monitoring assesses the application of standards and whether regulatory goals have been met, respectively, but should be foundationally linked to validation activities, which determine and verify the underlying relationships between management and the landscape.

Implementation and effectiveness monitoring projects are the most common within Ontario's Adaptive Management framework, and the results of policy implementation, guideline applicability, and overall governance structure are regularly reviewed and modified (OMNRF 2010). Effectiveness monitoring is also explicitly required by mandate of the policy, e.g. see the CFSA, which states that indicators must be developed to "assess the effectiveness of activities in achieving management objectives and to assess the sustainability of the Crown forest". Formal mechanisms for effectiveness and implementation monitoring are also outlined under the *Stand and Site Guide* (OMNRF 2014b), which guides the set-up for pilot testing, effectiveness monitoring, and modification of coarse and fine filter direction within an adaptive management context.

Although a significant number of guidelines and treatments may not require additional testing as they have already been trialed through forest management planning, or supported by a large body of scientific literature, the existing governance design emphasizes the refinement of existing practices, rather than the testing of alternative approaches or operational extremes. In practice, it may only be necessary to consider additional fine-filter direction, but larger-scale research, particularly in complex and new production systems such as greater utilization of forest biomass for bioenergy, would bolster the legitimacy and integrity of future policy development.

A review by Berch et al. (2011) based on the 2008 workshop *"The Scientific Foundation for Sustainable Forest Biomass Harvesting Guidelines and Policy"* held in Toronto summarized several knowledge gaps reported by participants. Habitat attributes and population dynamics were found to be poorly understood, particularly in the habitat value of fine woody debris, quantity of residues removed in comparison to natural disturbance, and the sensitivity of species to removals. Canadian studies on biodiversity were also found to be focused more on bird and mammal responses to biomass removal, which contrasted with the Fennoscandavian studies that concentrated on fungi and insect species associated with deadwood.

Validation monitoring activities have been conducted on a limited scale through the Island Biomass Study Project and the Great Lakes Biomass Harvest Project, which built on existing provincial understanding and research base for whole-tree harvesting spanning the early 1990s. Both projects continue to be active to the time of this writing, and utilize representative harvest

method and intensities. However, they may be unrepresentative of current or future extraction systems and mechanical configurations used for commercial biomass harvest (e.g. see Ghaffariyan et al 2017), or allay other concerns over biodiversity (Berch et al. 2011), and temporal scales for biomass harvest effects. Previous projects have been criticized for project delivery and planning, illustrating the difficulty of initiating long-term studies especially where competing perspectives on management, agencies, and timelines are involved (Morris and Duckert 1999).

Institutional design can have an immense influence over the implementation and design of adaptive management schemes. Costanza et al. (1998) identified six core principles for sustainable environmental governance including: responsibility, scale-matching, precaution, adaptive management, full cost allocation, and participation. Biomass research under adaptive management must involve monitoring at relevant scales, operational constraints, and on representative sites. Affected stakeholders must also be engaged in a more active way, with all risks and benefits identified and allocated appropriately. High cost of data acquisition has been identified by McLain and Lee (1996) as a main challenge for successful adaptive management. The mismatch between perceived costs and benefits may significantly hinder supportive investments as risks and costs are borne in the short term, while the benefits of monitoring are generally realized over a longer time frame. Future research could focus on critical criteria for sustainable biomass harvest; for example, the biodiversity risk assessments using for example a response curve of specific habitat elements, threshold levels for biomass recovered by thinning operations, the management of residues on landings and roadside, and transport.

7.4 INDIGENOUS PEOPLES' RIGHTS

Social sustainability is an essential value endorsed by basically every international sustainable development agreement. Procedural rights for First Nations groups were granted through the Canadian Constitution Act (1867), involving a right for consultation, rather than a veto for approval over resource extraction. The Class Environmental Assessment for Timber Management on Crown Lands in Ontario introduced Condition 77 in 1994 (Condition 77 became Condition 34 in 2003) directed the Ontario Ministry of Natural Resources to negotiate with Aboriginal communities on a local level to identify and implement means of increasing economic development opportunities related to forestry (see Koven & Martel 1994). More recently, Canada endorsed the United Nation Declaration on the Rights of Indigenous Peoples (UNDRIP 2019). A literal reading of the UNDRIP declaration, particularly if judicial decisions grant Indigenous communities a complete right to self-determination, could result in tension among natural resource (including forestry, oil and gas, mining) stakeholders and a fundamental change in governance and government (see, for example McCarthy 2016). It is anticipated that UNDRIP related negotiations will take some time to resolve in Canada, given the complexity of issues involving the standing of Indigenous people, contractual relations with, for example, the forest products industry (e.g. tenure agreements), and regulatory authority of provinces (e.g. for management of Crown forests), and federal government. Despite frustration with Condition 34 (see Fernandes 2006), one might anticipate a future where Indigenous people comprise a more significant proportion of owners, managers, employees of timber operations and forest management in northern Ontario.

7.5 CARBON BENEFITS

Since global trade in wood pellets and other forest-based bioenergy markets are generally driven by carbon policies (see, for example Smith et al. 2016; Thiffault et al. 2016), feedstocks must demonstrate carbon savings across the entirety of their supply chains to be exported successfully from Canada to Europe. Ontario conducted a Forest Carbon Policy Project (Environmental Registry of Ontario 2019c), which considered both market and policy approaches to increase the potential

of Crown forests to reduce emissions and remove carbon from the atmosphere. Forest carbon management policies could influence the "operations occurring prior to transporting the wood to the mill gate, including access (e.g., roads and landings), harvesting (e.g., cutting and hauling), renewal (e.g., regeneration), tending, and protection (e.g., from insects, disease, and wildfire)." However, policy developments present an opportunity to align international carbon mitigation targets and associated incentives with the province's sustainable forest management policy framework and further scientific evidence and public consensus regarding Ontario's carbon mitigation potential, which could reap benefits associated with the desirability and eligibility of Canadian wood pellets to EU or Asian energy production markets.

8 Summary and conclusions

Biomass harvest for the purpose of wood pellet production is an emergent industry in Ontario that, at present, constitutes a minor level of production and economic impact compared to the traditional forest products sector. In 2017/2018, biomass use for cogeneration was 4.2% of total forest products harvested, which was estimated to be 0.6 million m^3 of a total of 15 million m^3, including composite, paper, pulp, sawmill and veneer (van Kerkhof 2018). However, there has been strong interest by the provincial government in establishing a robust bioeconomy, and rising demand of wood pellets from the European Union has opened markets for overseas export, driving opportunities for international trade. A critical review and risk assessment of Ontario's policy framework for the sustainable management of biomass harvest is therefore timely.

This report summarized and assessed the adequacy of Ontario's policies, and opportunities for supply chain governance through certification, as well as comparing governance frameworks applicable to sustainable biomass harvest in Ontario and other biomass-producing regions. Our analysis indicated that future biomass harvest are likely to occur within the boreal forest and Great Lakes - St. Lawrence regions of Ontario under full tree harvest operations, with feedstocks primarily obtained as harvest residues from existing, traditional forest products industry commercial activity.

As no legislation specific to bioenergy feedstock production exists in Ontario, current biomass harvests are conducted under the Ontario SFM and adaptive management framework, which encompasses mandatory planning, stakeholder consultation, monitoring, and self-assessment and government control at the site level to achieve mandated sustainable management goals. Compared to the private certification standards of SFI and CSA the provincial *Stand and Site Guide* contained the most site-specific, complex, substantive and quantifiable operational guidance. The prescriptiveness of the Guide also superseded national-level forestry policy in Norway and Sweden, and generally also certification standards applicable in these countries. Private certification schemes were less prescriptive in every policy variable assessed but promote a more comprehensive concept of SFM and act as an additional monitoring tool to ensure that provincial standards are met. Canadian forestry certification standards corresponded to Nordic standards. The combined use of the provincial policy framework and private forest certification in Ontario results in comprehensive forest planning, audit, and monitoring to achieve SFM.

The documentation of sustainability of forest biomass harvests in Canada is supported by a diverse monitoring platform at the federal and provincial levels, which provide transparency and up-to-date information on the advancement of sustainability of domestic and international sustainability commitments. An extensive monitoring platform tracks forest conditions, trends and site quality through time-and-space observations at the national level. In Ontario, monitoring requirements are driven by the CFSA, *Environmental Assessment Act*, and requirements for Forest

Management Plans, which necessitate frequent assessments of compliance, policy effectiveness, and general resource attributes. New findings are applied in the revision of policy, enabling the constant update of guidelines to the latest findings and social demands. Internal review of effectiveness and implementation also promote achievement of sustainable results on the ground, although our analysis revealed that landscape-level intensive monitoring for biomass harvest had only been conducted on a few sites, and under a limited scientific program scope, which may not be sufficient for the timeframe and geographic range of all biomass collection activities within the province.

Key to increasing the effectiveness and efficiency of sustainability policies will be an integrated vision for biomass harvest requiring improved coordination amongst government ministries, rigorous scientific research to appropriately review and revise adequate SFM policy solutions, and expanded consultation with stakeholders to ensure that new policies are acceptable and increase opportunities for collaboration. Adaptive learning specifically related to biomass production and harvesting may benefit from monitoring approaches targeted specifically at biodiversity, with intensive monitoring at a small number of benchmark sites to validate effectiveness of the applied practices (sensu Smith et al. 1999).

As witnessed by the continuing evolution of energy sector driven regulation for SFM in the EU, the governance of sustainability of biofuels remains a developing field that is still adjusting the realities of production, customer and stakeholder demands, and socio-environmental impact globally. Ontario has already taken a clear and systematic step towards SFM, and is well poised to take advantage of future opportunities from bioenergy.

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10 APPENDIX A – Additional tables and figures

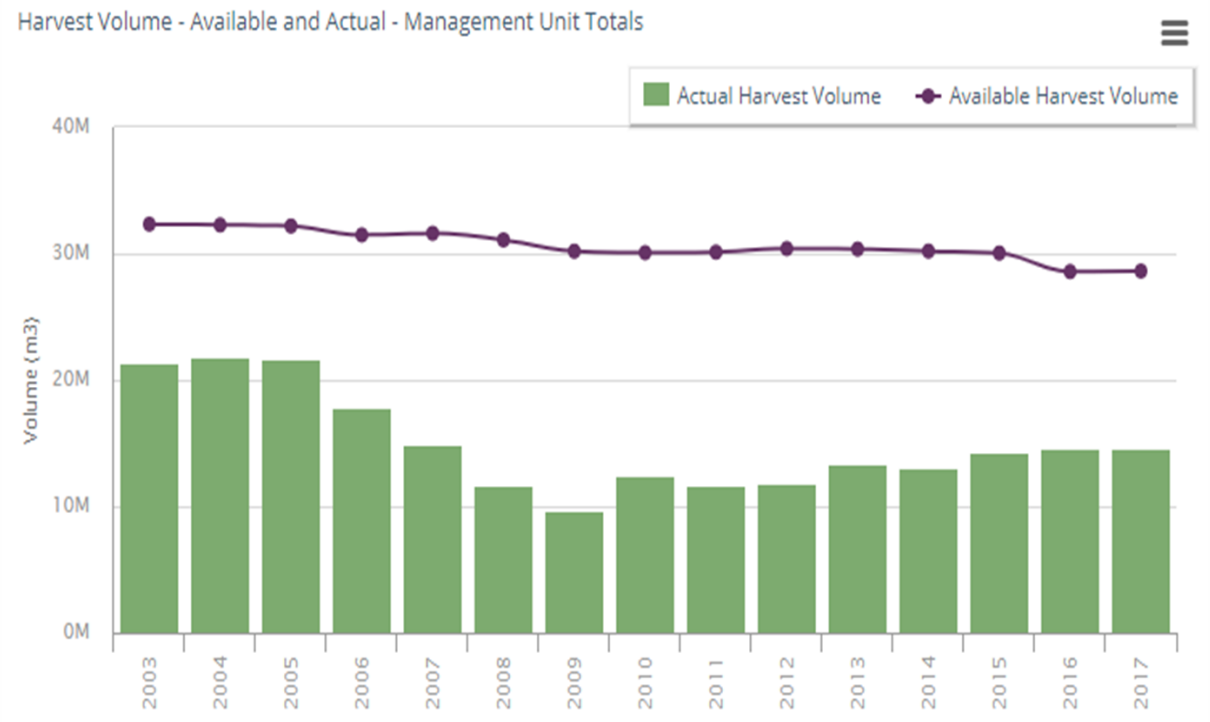

Figure A1. Annual Allowable Volume versus harvested volume (Maure 2019, OMNRF).

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