Sustainable Watersheds for Carbon Offsets:

Biomass harvesting for phosphorus capture, habitat renewal and carbon emissions reductions

IISD REPORT

IISD
International Institute for Sustainable Development

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August 2019

Published by the International Institute for Sustainable Development

International Institute for Sustainable Development

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Written by Richard Grosshans, Bala Viswanathan, Phil Gass and Lorne Grieger

Executive Summary

For the last decade, IISD's Bioeconomy project has actively demonstrated innovative watershed management practices, to harvest cattails and other plants from marginal agricultural land, water retention sites and roadside drainage ditches to remove nutrients and contaminants taken up by the plants. The abundant plant biomass is used for energy, bedding, compost and soil enhancement, which generates valuable carbon offsets through carbon dioxide displacement and sequestration. This use of waste material is the foundation of the bioeconomy, where biological waste resources and waste streams are converted into value-added products, and is at the core of the "circular economy," where resources are maintained in the economy for as long as possible and the generation of waste is reduced.

Using this type of "unconventional" waste biomass also has other added benefits, which raises the environmental profile of generated offsets (carbon dioxide equivalent). Harvesting cattail and other grasses from managed areas in the watershed removes captured phosphorus before it gets into lakes, which can be recovered and used as an agricultural fertilizer. Harvest and removal of the biomass also improves habitat health and biodiversity, improves flow in water retention sites to reduce flood impacts and helps control invasive species. Recognizing these added benefits enhances the environmental quality of carbon reduction offsets and connects them with other provincial and federal priorities.

This report highlights watershed management activities from 2018 and 2019 during the fall and winter seasons to optimize harvesting and processing methods of blended biomass with industry partners. It also explores greater economic and efficient end uses of biomass material, such as bedding and compost for soil carbon sequestration, to meet the demand of the evolving biomass and carbon markets in Manitoba. One major focus is harvesting roadside drainage ditches as a viable alternative to conventional methods of mowing, herbicides and excavation. Removing accumulated plants and debris improves water flow to reduce back flooding; maintains the integrity of the ditch versus digging out the ditch bottom; removes phosphorus and contaminants taken up by plants; and enables the use of harvested biomass for energy, bedding, compost and soil enhancement.

With the greatest demand of the material for use as livestock bedding and compost, end use of the material in 2018 and 2019 shifted away from bioenergy to focus on organic material for improving soil health. Forage chopped material was used for compost and for livestock bedding, and was later land applied to improve soil health. Land applying composted material recycles captured nutrients such as nitrogen and phosphorus and adds important organic material and carbon back to the soil, which aligns with the goals of the circular economy. An initial review examines the benefits of land applying the biomass to improve soil health instead of burning it for bioenergy.

Current global carbon markets and carbon initiatives since the Kyoto Protocol in 1997 and the recent Paris Agreement in 2015 are also examined to explore lessons from global carbon markets for Canada and Manitoba. In addition, the report assesses applicable carbon market verification methodologies to identify those that could be considered and modified for ongoing and future bioeconomy initiatives.

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Abbreviations and Acronyms

ACR	American Carbon Registry
ARB	Air Regulation Board
CAR	Climate Action Reserve
CARB	California Air Resources Board
CATR	Cap-and-Trade Regulation
CD	conservation district
CDM	Clean Development Mechanism
COP	Conference of the Parties
ERT	Emission Reduction Tons
GHG	greenhouse gas
IISD	International Institute for Sustainable Development
MAFRD	Manitoba Agriculture, Food and Rural Development
MBLL	Manitoba Liquor and Lotteries Corporation
MELCC	Ministère l'Environnement et de la Lutte contre les changements climatiques
PAMI	Prairie Agricultural Machinery Institute
REDD	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
RGGI	Regional Greenhouse Gas Initiative
RM	rural municipality
SRRCD	Seine–Rat River Conservation District
VCS	Verified Carbon Standard
VCU	Verified Carbon Units
WCI	Western Climate Initiative

1.0 IISD's Bioeconomy Project (2017–2019)

1.1 IISD Innovation in the Bioeconomy

For the last decade, the International Institute for Sustainable Development (IISD) and partners have engaged in innovative watershed management to harvest cattails and other plants from marginal agricultural land, water retention sites and roadside drainage ditches to remove nutrients and contaminants taken up by the plants. The abundant plant biomass is used for energy, bedding, compost and soil enhancement, which also generates carbon offsets. Use of the biomass as a low-carbon fuel for heating to displace high-carbon-emitting fossil fuels reduces global carbon emissions through carbon dioxide displacement and sequestration, while use of the material for bedding and compost sequesters carbon when used for soil enhancement to build and store soil organic carbon. This use and reuse of what is essentially waste material to produce value is the foundation of the bioeconomy, where biological waste resources and waste streams are converted into value-added products, such as food, feed, bio-based products and bioenergy (European Commission, 2012). It is also the core of the "circular economy," where the value of products, materials and resources is maintained in the economy for as long as possible (European Commission 2019).

Using this type of "unconventional" waste biomass also has other added benefits, which raises the environmental profile of generated carbon dioxide equivalent (CO_2e) offsets beyond carbon use. Plants such as cattail can sequester phosphorus—the nutrient responsible for Lake Winnipeg's eutrophication-causing algae blooms—as they grow. Harvesting cattail and other grasses from managed areas in the watershed removes captured phosphorus before it gets into the lake, which can be recovered and used as an agricultural fertilizer. Harvest and removal of the biomass also improves habitat health and biodiversity, improves flow in water retention sites to reduce flood impacts and helps control invasive species. Recognizing these added benefits enhances the environmental quality of carbon reduction offsets and connects them with other provincial and federal priorities, such as the health of Lake Winnipeg.

1.2 Sustainable Watershed Management Activities: Phosphorus capture and carbon reductions

The biggest challenge for the watershed management work each year is dealing with unpredictable weather conditions and the impacts on access to harvest sites. Extremely wet conditions in fall 2018, for example, delayed harvesting activities, but a moderate early winter season allowed harvesting well into January, until heavy snowfalls shut down harvesting activities. Another challenge is working with the changing priorities of industry and delays when working around industry schedules. We also discovered that the initial high-priority drainage ditches were much more complicated to harvest, and an attempt to obtain funding for specialized equipment was unsuccessful. This required the project team to identify new harvest sites and new funding options.

Section 2 of this report summarizes the watershed management activities in 2018 and 2019. Efforts during the fall and winter seasons continued to optimize harvesting and processing methods of blended biomass with industry partners. We also continued to explore greater economic and efficient end uses of biomass material, such as for bedding and compost for soil carbon sequestration, to meet the demand of the evolving biomass and carbon markets in Manitoba.

The long-term monitoring and harvesting of the Pelly's Lake water retention project near Holland, Manitoba, continued as one of the primary cattail harvest locations. But new locations in 2018 and 2019 are expanding our understanding of how to carry out proper watershed retention management, as well as how to apply management

concepts developed at the Pelly's Lake site. Monitoring and research began at the De Salaberry water retention project east of St. Malo, Manitoba, to understand how this system currently functions and to develop a hydrodynamic flood and nutrient model to be applied to retention projects in Southern Manitoba.

A new project was also initiated in 2018 to harvest roadside drainage ditches, in collaboration with the Seine–Rat River Conservation District (SRRCD) and the Rural Municipality (RM) of Springfield. This project successfully proved that harvesting rural roadside drainage ditches is a viable alternative to the conventional annual ditch management methods of mowing, herbicides and excavation. Harvesting and removing accumulated plants and debris 1) improves water flow to reduce backflooding; 2) maintains the integrity of the ditch versus digging out the ditch bottom; 3) removes phosphorus and contaminants, which are taken up by plants instead of being washed downstream; and 4) enables the use of harvested biomass for energy, bedding, compost and soil enhancement for carbon storage and greenhouse gas (GHG) offset reductions. The results of this pilot demonstration project will improve how drainage ditches are managed by RMs in the Lake Winnipeg Watershed. This project demonstrated a more sustainable management approach that meets the necessary objectives to maintain roadside drains, reduces phosphorous loading to Lake Winnipeg and produces a valuable biomass product.

1.3 Evolution of Biomass Demand: Bedding, compost and soil health

Collaborations with industry and partners continues to evaluate the best use of the harvested biomass material to maximize benefits and reduce costs. Demand for the material in 2018 and 2019 proved to be for livestock bedding and compost: applying the carbon- and nutrient-rich organic material back on the land to improve soil health and carbon storage. In 2018–2019, end-use of the material shifted away from bioenergy to focus on organic material for improving soil health. Forage chopped material proved an excellent addition to the compost and was sent to operations around the Steinbach area for livestock bedding. Bedding material was in significant demand for 2018–2019, and harvesting couldn't keep up with demand. The mixed-use bedding, manure, compost will be land applied to improve soil health and will be monitored in 2019.

Section 3 of the report includes a review on the benefits of land applying the biomass to improve soil health, instead of burning it for bioenergy. Land applying the composted material recycles the captured nutrients such as nitrogen and phosphorus and adds important organic material and carbon back to the soil, which aligns better with the goals of pursuing a circular economy. From a simple economics and logistics perspective, using it for bedding and compost also eliminates many of the issues when trying to use it for energy—such as moisture, baling and processing, storage, and timing of harvest—which greatly improves efficiencies and decreases overall costs.

1.4 Global Carbon Markets and Verification Methodologies

The carbon emission reductions landscape in Canada, and more locally in Manitoba, has seen significant change over the past several years but has not moved to a national or international carbon offset market with a standard offset price on carbon emissions. In a move to meet Canada's commitment under the Paris Agreement, where countries agreed to limit global temperature increase to 1.5°C, the federal government in 2019 brought in the Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada, 2019). The Pan-Canadian Framework puts a price on carbon emissions in an attempt to motivate GHG emitters to decrease emissions. Carbon prices begin at CAD 10 per tonne and increase by CAD 10 per year until they reach CAD 50 per tonne by 2022.

But provincial governments in Manitoba, Saskatchewan, Alberta and Ontario currently are against the federal carbon pricing, or "carbon tax," arguing they have better plans to combat carbon emissions. In Manitoba, the provincial

Climate and Green plan "focuses on cleaner water, conservation of nature, economic opportunity and effective steps to reduce emissions" (Government of Manitoba, 2019). Under the federal plan, provinces that do not implement their own carbon plan by 2019 will have the federally mandated carbon tax, or backstop, imposed on them. The 2019 Canadian federal elections will decide the fate of the federal carbon tax and carbon pricing in Canada.

Section 4 of this report explores the current global carbon markets and carbon initiatives since the Kyoto Protocol in 1997 and the recent Paris Agreement in 2015, to provide lessons from global carbon markets for Canada and Manitoba. Section 5 explores applicable carbon market verification methodologies to assess and identify those that could be considered and modified for IISD's sustainable watersheds project, which will be further explored in IISD's ongoing Bioeconomy Project.

1.5 Manitoba Liquor and Lotteries Funding Support

Continued funding support from Manitoba Liquor & Lotteries Corporation (MBLL) has allowed IISD to build a strong bioeconomy research program over the past decade. It has enabled IISD researchers to apply developed concepts locally in partnership with Manitoba's Conservation Districts (CDs), in the Great Lakes to manage invasive species, and internationally through water retention management projects in Minnesota and North Dakota and paludiculture peatlands management strategies in Europe. IISD experts consult on provincial and federal government policies, specifically on the Manitoba Climate and Green Plan, the provincial carbon tax, green/natural infrastructure, Lake Winnipeg and Netley-Libau Marsh, climate resilience and best management practices in agriculture, and global water security. Harvesting cattail and other unconventional biomass sources is established in provincial and federal programs as an integral component of Lake Winnipeg nutrient-reduction strategies.

This past year's investment in carbon offsets by MBLL provides tangible evidence of its continued commitment to corporate social responsibility and sustainability principles in action and its role as a continuing leader in Manitoba in sustainable energy, local carbon offset investment, carbon emission reductions and the protection of the Lake Winnipeg watershed.

1.6 Project Outreach

1.6.1 Communications and Media

1. The future of biomass in Manitoba – Manitoba Agriculture website
2. 'Natural infrastructure' — retain what you have; restore what's lost – Manitoba Cooperator, October 15, 2018
3. First Nations join public and private organizations to restore Netley Marsh – Water Today, February 28, 2019
4. Proposed regulatory changes could accelerate Manitoba wetland loss, conservation groups say – CBC News, January 26, 2019
5. Cattail Islands: A step towards cleaner water – Steinbach Online, July 2, 2018
6. Floating treatment wetland launched in Riley Family Duck Pond – Manitoba Post, August 2, 2018
7. Fake island to help Assiniboine Park pond – CHVN 95.1FM, July 26, 2018
8. Canada should copy Europe when it comes to the bioeconomy – IISD Blog, R. Grosshans, December 14, 2018
9. #Canada should take a leaf out of Europe's books when it comes to #SustainableEnergy future – EU Reporter, R. Grosshans, December 12, 2018
10. Making biomass big business in Manitoba – IISD Blog, R. Grosshans, February 26, 2018

11. The multiple benefits of natural infrastructure – IISD Blog, D. Roy, August 27, 2018
12. Let's talk, not bicker, about Canada's energy future – IISD Blog, J. McDonald, July 6,2018

1.6.2 Publications

1. Bansal et al. (in press). *Typha* (cattail) invasion in North American wetlands: Biology, regional problems, impacts, desired services, and management. *Wetlands*.
2. Grosshans, R.E., Lewtas, K., Stanley, M. & Gunn, G. (in press). *Floating treatment wetlands and plant bioremediation: Nutrient removal by wetland filtration in eutrophic freshwater lakes*. Winnipeg: IISD.
3. Svedarsky, D., & Grosshans, R. (in press). Integrated management of invasive cattails for wetland habitat and biofuel in the Northern Great Plains of the US and Canada: A review. *Mires and Peat.*
4. Roy, D., Grosshans, R., & McCandless, M. (2019). *IISD's response to Manitoba's proposed new water rights regulations to protect wetlands and make drainage more sustainable in the province* (Policy Brief). Retrieved from https://www.iisd.org/library/iisd-response-manitoba-proposed-new-water-rights-regulations-protect-wetlands
5. Grosshans, R., Stanley, M. & Bath, S. (2018). *Floating treatment wetlands: Keeping our fresh water clean and healthy.* Retrieved from https://www.iisd.org/library/floating-treatment-wetlands-keeping-our-fresh-water-clean-healthy; Web-based Storybook: https://iisd.org/story/floating-treatment-wetlands/
6. Stanley, M. & Grosshans, R. (2018). *How to build a floating wetland* (Video). Retrieved from https://www.iisd.org/library/how-build-floating-wetland
7. Grosshans, R., & Bath, S. (2018). *Manitoba's biomass fuel: Protecting our environment and saving us money.* Retrieved from https://www.iisd.org/library/manitobas-biomass-fuel-protecting-our-environment-and-saving-us-money
8. Grosshans, R., Gunn, G., & Roy, D. (2018). *Manitoba Bioeconomy Atlas* (Web-based mapping tool). Retrieved from https://www.iisd.org/library/manitoba-bioeconomy-atlas. The Manitoba Bioeconomy Atlas demonstrates the economic and ecological value of common wetland plants as a marketable feedstock for biomass energy—all with the goal of creating a healthier Lake Winnipeg basin and developing a Manitoba bioeconomy.
9. Grosshans, R.E., Bath, S. & Roy, D. (2017). *How to best manage water retention sites to protect Manitoba's environment*. Retrieved from https://www.iisd.org/sites/default/files/publications/best-manage-water-retention-manitoba.pdf

1.6.3 Publication Highlights

POLICY BRIEF – MANITOBA'S BIOMASS FUEL: PROTECTING OUR ENVIRONMENT AND SAVING US MONEY

By Richard Grosshans, Sumeep Bath (2018)

Key messages: Biomass is a viable, abundant and environmentally sound source of renewable energy in Manitoba. Along with less familiar "ecological" biomass sources, it can provide an even greater host of environmental and economic benefits. The Government of Manitoba can play a crucial role in enabling bioenergy markets in the province so that Manitobans can enjoy those crucial benefits.

- Manitoba has tremendous potential to incorporate bioenergy in its growing renewable energy portfolio, as Canada strives to lower GHG emissions.

- Biomass, abundant in the province and in high demand, can be converted into a renewable, locally sourced and feasible alternative to fossil fuels.
- Less familiar unconventional or ecological biomass (such as cattail) provides an even greater set of environmental and economic benefits.
- The Government of Manitoba has an opportunity to champion and facilitate bioenergy markets through financial support, coordination and by supporting markets.

POLICY BRIEF – HOW TO BEST MANAGE WATER RETENTION SITES TO PROTECT MANITOBA'S ENVIRONMENT

By Richard Grosshans, Sumeep Bath, Dimple Roy (2017)

Key messages: Water retention sites—vital for protecting Manitoba from floods—must be well managed for Manitobans to enjoy the abundance of additional environmental benefits they bring.

- Increasing water retention in Manitoba is an important way to reduce risks from floods, drought and nutrient loading. It also provides a host of other environmental benefits.
- These water retention sites must be strategically managed to effectively protect the environment and provide value for money—mere implementation is not enough.
- Managing water retention sites includes consideration of engineered wetlands, how long the water is retained for, how water levels are controlled and when biomass is harvested.

ARTICLE – CANADA SHOULD COPY EUROPE WHEN IT COMES TO THE BIOECONOMY

By Richard Grosshans (2018)

This article first appeared in EU Reporter on December 12, 2018, and as an IISD Blog on December 14, 2018 (Grosshans 2018a, Grosshans 2018b). This article explains how Canada needs to learn from the bioeconomy successes of Europe and the recently announced EU Bioeconomy Strategy. The strategy continues that continent's legacy of advancing biological solutions to environmental questions and strategically highlights the economic benefits of the approach with a strong focus on jobs, growth and investment in the EU. If Canada were to up its game in the bioeconomy sector, the impact would be significant. In fact, replacing just 5 per cent of Canada's gas supply with renewable gases would reduce GHG emissions by 10 to 14 megatonnes annually. We are already moving in the right direction with the proposed Clean Fuel Standard and the newly released National Bioeconomy Strategy.

2.0 Watershed Harvest Management Activities (2017–2019): Phosphorus capture, habitat renewal and carbon emissions reductions

2.1 Harvesting

Since 2012, IISD and the Prairie Agricultural Machinery Institute (PAMI) have built expertise in large-scale harvesting of cattail and other unconventional biomass sources from a variety of land areas. In 2018 and 2019, harvesting was carried out in both water retention and roadside ditch environments by two methods: 1) swathing and baling to be shipped and shredded and 2) forage chopping to produce chopped cattail material that resembles wood chips. PAMI used equipment commonly available from the hay and forage industries for cutting and collecting cattails/mixed grasses and tested the capabilities of existing forage equipment for cattail harvesting in various settings. Previous research highlighted the ability of current equipment capable of harvesting cattails, provided the field conditions are suitably dry.

Figure 1. a) MacDon rotary disc mower conditioner, b) harvesting in Pelly's Lake, c) Case IH Puma 200 CVT tractor with a Challenger LB34B large rectangular baler, and d) shipping bales at Pelly's Lake.

2.1.1 Pelly's Lake: Swathing and baling

In fall 2017, cattail and mixed grasses were harvested from the Pelly's Lake water retention project by swathing and baling. Cattails/mixed grasses were cut and baled with a rotary disc mower between October 17 and October 20, 2017, similar to the MacDon units used in previous years (Figure 1a and b). In 2017 a New Holland (Durabine 416) mower conditioner was used. One of the major challenges of using conventional equipment to harvest in marginal land areas where cattail grows is the potential for wet soil conditions, a hazard that results in lower harvesting efficiency. Harvested material was baled October 25 to October 30, 2017 using a Case IH Puma 200 CVT tractor with a Challenger LB34B large rectangular baler (Figure 1c). The rectangular bales were collected, and field stored at Pelly's Lake wetland in November 2017. A tarp was used to provide temporary cover for the bales before the bales were shipped off-site. The bales were shipped fall 2017 to the Rock Lake, Greenwald and Miami Hutterite colonies to be shredded for energy use. A total of 24 rectangular bales can be shipped on a single step-deck trailer, up to 32 bales depending on size of truck and bales.

2.1.2 Pelly's Lake: Forage chopping

Initial field trials were performed on windrowed cattails at Pelly's Lake in early December 2017. A New Holland (NH900) forage harvester was used to chop the cattails into smaller pieces resembling wood chips (Figure 2) and field stored under a tarp on site. Cattail swaths were forage chopped at an estimated travel speed of 3–4 mph, and no major issues were observed. Forage chopping eliminated the need and cost of additional steps of baling, collection, stacking, moving and bale shredding. Material was shipped to Rock Lake Hutterite Colony in winter 2018 for energy evaluations.

Figure 2. a) chopped cattails from the NH900 forage harvester close-up resembling wood chips, b) chopped material loaded into B-train for shipping.

In 2018–2019, all harvested cattail/mixed grasses at Pelly's Lake was swathed and forage chopped. Harvesting took place in October and November 2018. A Kubota tractor (M7-171) and MacDon mower (R113 PT) were used to cut and windrow the cattails. The windrowed cattails were chopped and collected with a New Holland forage harvester (NH-900) and Rex forage wagon. To increase the length of the chopped material, half the knives were removed from the forage harvester and the cutter head was operated at the slowest setting. Collected material was shipped to Rock Lake Hutterite Colony in fall 2018 for compost trials and a portion was transported to PAMI's facility in Portage la Prairie for densification trials with their "mobile densification system."

2.1.3 Rural Municipal Roadside Ditch Management

A cattail and drainage management workshop in spring 2018 successfully engaged landowners, municipal and provincial government, conservation districts (CDs), and industry. This workshop identified high-priority roadside ditches where harvesting activities could be demonstrated. Steep-sided narrow ditches - initially a focus of this project - proved to be a challenge. In fall 2017 and 2018, steep-sided ditches were harvested by the RM of Springfield for drain management utilizing existing Herder ditch mowing equipment already used by several RMs and CDs in Manitoba (Figure 3). This method uses a ditch mowing bucket attachment on an excavator arm, and, while effective, it is slow and costly. Specialized ditch harvesting equipment is available from the Netherlands, such as the Herder Vacuum Flail Mower and could be used to effectively and safely manage steep-sided ditches more efficiently and at less cost than current practices. In 2018–2019, flat-bottomed roadside ditches with large accumulations of plants and debris were highlighted as priority sites for the SRRCD with overlap with the RM of Springfield. These sites proved to be excellent sources of cattail/mixed grasses and where ditch harvesting could be demonstrated most effectively and efficiently with conventional cutting and forage equipment.

Figure 3. Ditch management with the Herder bucket mower attachment for cutting and removing ditch vegetation.

In 2018–2019, roadside ditches were harvested in the Whitemud Conservation District and in the SRRCD from October 2018 to January 2019 with a Case IH tractor (Puma 200 CVT) and either a MacDon mower (R113 PT) or Kuhn mower (FC 353 GC). With less snow accumulation in the early part of the winter, harvesting continued well into January 2019 (Figure 4). After the first snowfall, the amount of harvested material was reduced due to the snow-filled field conditions. Mower cutting height was adjusted to above snow level; however, only the exposed top portion of the cattails could be cut. Harvesting was still possible in winter snow conditions, but the amount of material collected was considerably reduced.

Similarly to Pelly's Lake, the windrowed cattails were reduced in size with a New Holland forage harvester (NH-900) and Rex forage wagon. The collected material was piled on the field until it was loaded for transportation (Figure 4d). All forage chopped material from the SRRCD in the Steinbach area was shipped to nearby farms for animal bedding (sheep and cattle).

Figure 4. a) Kubota tractor and MacDon disc mower harvesting roadside ditches, b) swathed roadside ditches, c) swathed roadside drainage areas in winter, d) forage chopped material being loaded for shipping.

2.1.4 Urban Harvesting in the City of Winnipeg

Each year, the City of Winnipeg harvests cattail from drainage ditches throughout the city to maintain the flow and integrity of the ditch drainage. IISD previously collaborated with the city on the urban cattail project, Cattail for Clean Community Waterways: Turning Urban Plants into Compost and Bioenergy (Zubrycki & Grosshans, 2013). Through this project, waste material harvested from city ditches was diverted away from Brady Road general landfill to the Brady Road compost facility and used as a biomass fuel for heating. An impetus for this came from a need to improve and enhance water quality in urban areas and in downstream Lake Winnipeg, and to quantify the amount of phosphorus that could be removed through urban biomass harvesting. The project began in 2013 with the harvesting of cattail (*Typha* spp.) and prairie grasses at numerous sites within the city. This material continues to be delivered to the Brady Road compost facility and incorporated into the yard waste compost swaths each fall as part of the City of Winnipeg maintenance program, with excellent results. Each year, up to 500 tonnes of material is diverted, along with approximately 350 kg of phosphorus removed from ditches in the harvested material. Without diversion in previous years, this material was either left to decompose on the side of ditches or sent to general landfill. Diverting from landfill to compost reduced GHG emissions by over 200 tonnes. Composting cattail creates a net GHG benefit when compared to landfilling, and compost has environmental benefits as a natural fertilizer.

2.2 Use of Biomass

2.2.1 Bioenergy: Biomass heating in Manitoba's Hutterite communities

Since 2010, IISD's bioeconomy work has had a central focus on biomass for bioenergy for large-volume use of harvested cattail and mixed grass. In 2014 the Manitoba government's ban on the use of coal for space heating came into effect, with a three-year transition period to 2017 for coal users to switch over to another form of lower-carbon fuel. According to the Province of Manitoba, many of the 200–300 known coal users switched to biomass; the rest switched to electricity or natural gas with a few remaining micro-coal users. IISD continues to engage with industry, government and Hutterite communities in Manitoba on biomass projects. Hutterite communities are some of the biggest users of biomass for space heating, as many of them are not located near natural gas pipelines and were the most impacted by the coal ban.

Several Hutterite communities have been active partners with IISD, producing blended cattail fuel, combustion testing and using harvested material in stoker boiler systems. IISD collaborated with Greenwald Hutterite Colony and industry partner Biovalco to produce wood-based fuel pellets, and to utilize shredded cattail and other grasses to produce blended cattail:wood:grass fuel pellets. Biovalco has been an integral industry partner and assisted Greenwald Hutterite Colony to upgrade the fuel pellet facility, convert the facility to use wood waste to produce wood-based fuel pellets as a primary product, and utilize shredded cattail and other grasses harvested as part of this project.

Blended cattail:wood:grass fuel pellets have been used in biomass heating systems on the Greenwald Colony, Brightstone Colony, at Providence University College and in smaller stove facilities at the Living Prairie Museum, The Forks warming hut, as well as by local farmers around Greenwald Colony. The Living Prairie Museum in Winnipeg continues to use exclusively cattail blended fuel pellets for the past number of winters in their fuel pellet stove and are promoting the project concepts through education.

The bioenergy focus for the winters of 2017 through 2019 has been evaluating coarse shredded, forage chopped and larger densified fuel cubes for use in larger stoker boiler systems. The larger fuel sizes significantly reduce the cost and energy required for processing fuel pellets. With shredding, the consistency of the material is very fibrous and tangled as it is ripped apart, and a small screen size is needed to break it down to a suitable size that will not cause feeding issues. The consistency of the forage chopped material resembles woodchips and has excellent characteristics for feeding into the boiler system. This requires less processing effort and was the primary process in 2018 and 2019.

Although there was considerable resistance to shift from coal in the early phase of the coal ban, comments from Hutterite members following the transition has been positive for biomass versus coal heating:

1. Several communities used it as an opportunity to replace aging coal-burning systems with modern, efficient, automated and clean biomass boiler systems.
2. Replacement of aging coal-burning systems improved heating efficiency, air quality in the community and time commitment needed to manage the heating system.
3. Biomass heating allowed for more heating and better ventilation in pig barns, improving in-barn air quality and the health of pigs as well as workers in the barns.
4. Biomass heating is a better quality heat and there is less dirty ash to deal with compared to coal.

SHREDDED MIXED CATTAIL:GRASSES:WOOD

Combustion testing of shredded bulk cattail/mixed grasses was carried out at the Greenwald and Miami colonies during winter 2017 and Rock Lake Colony winter of 2018. Cattail/mixed grass bales were shredded with tub grinder hammermills to break down the material to the appropriate size for use in colony biomass systems with "walking floor" feed systems. Approximately ½- to ¼-inch screen size is needed for pelleting, while walking floor systems can handle much larger shred size, therefore requiring less shredding effort and faster shredding rates. Blended cattail:wood fuel was used for heating in the colony stoker boiler system utilizing different methods to compare efficiencies. Coarse shredded cattail/grass was much more efficient/cost effective than highly processed fuel pellets; however, heat value was less and loose light-weight shredded material caused feeding issues if the ratio of mixed cattail/grasses:wood was too high.

FORAGE CHOPPED CATTAIL:GRASSES

Combustion testing of blended biomass from forage chopped cattail produced good results. The forage chopped material resembled wood chips and fed much better than shredded bale material. Ultimately, loose cattail had good burn qualities either shredded or forage chopped, but moisture from storage and the light volume of shredded material continues to cause issues for use as energy. Over 500 tonnes of blended cattail:grass:wood fuel was combusted for heat energy. This was an excellent test on bale storage, longevity of stored biomass and heat value of biomass.

2.2.2 Waste Diversion and Urban Heating in the City of Winnipeg

Through the Cattail for Clean Community Waterways: Turning Urban Plants into Compost and Bioenergy project (Zubrycki & Grosshans 2013), waste material harvested from city ditches was used for compost and turned into compressed fuel pellets to be used for heating. The harvested plant materials were then compressed into biofuel pellets that were burned for heat in a City of Winnipeg pellet stove located at the Living Prairie Museum. An additional component in 2015–2016 involves the addition of cattail, harvested from urban ditches and prairie sites, into the city's large-scale composting facility. This material continues to be delivered to the Brady Road compost facility and incorporated into the yard waste compost swaths with excellent results. Each year up to 500 tonnes of material is diverted, along with approximately 350 kg of phosphorus removed from ditches in the harvested material.

2.2.3 A Shift from Bioenergy: Animal bedding, compost and soil health

In 2018–2019, end-use of the material shifted away from bioenergy to focus on organic material for improving soil health and soil carbon storage. Land applying the composted material adds important organic material back to the soil and recycles captured nutrients such as nitrogen and phosphorus from water and back onto the land where it is needed. Carbon removed from the atmosphere by the plants during growth and captured in the harvested material is all stored back in the soil and not released back into the atmosphere as it is when used for low-carbon energy. Using it for bedding and compost also eliminates many of the issues associated with using it for bioenergy—moisture, storage and timing of harvest—which greatly improves efficiencies and decreases overall costs.

Forage chopped material from Pelly's Lake was shipped to Rock Lake Colony and added directly to the compost, which proved an excellent addition. All material harvested for roadside drainage management in the SRRCD was sent to livestock operations around the Steinbach area for bedding. The forage chopped cattail and mixed grasses proved to be a good high-quality bedding for sheep and cattle, and harvesting could not keep up with the demand for bedding material in 2018–2019. The mixed-use bedding, manure, compost will be land applied in spring/summer 2019 and monitored for soil health and carbon storage.

2.2.4 The Carbuncle Warming Hut

In winter 2017–2018, IISD collaborated with The Forks and the University of Manitoba Department of Architecture to construct the first-ever heated warming hut as part of the annual Warming Huts Art & Architecture competition held by The Forks Market (Faculty of Architecture, 2017). Winning designs are constructed and placed along the Red River Mutual Trail located on the Assiniboine and Red rivers in Winnipeg, Manitoba. The collaborative warming hut design submission was "Carbuncle," which incorporated a gravity-fed fuel pellet heating stove, fuelled by locally sourced, Manitoba-produced wood fuel pellets and the blended cattail:wood fuel pellets (Box 1).

Box 1: Project Story: Carbuncle: Visually tactile

Excerpt from Carbuncle: A warming hut *(Faculty of Architecture, 2017)*

> One has in mind a whole range of complementary sensory perceptions which are registered by the labile body: the intensity of light, darkness, heat and cold; the feeling of humidity; the aroma of material; the almost palpable presence of masonry as the body senses its own confinement; the momentum of an induced gait and the relative inertia of the body as it traverses the floor; the echoing resonance of our own footfall. —Kenneth Frampton in *Toward a Critical Regionalism*
>
> Carbuncle is the project submission from the University of Manitoba, Faculty of Architecture for the 2017 Warming Huts Art & Architecture festival, at the Forks in Winnipeg, Manitoba. Four architecture studios, including 40 students from the Environmental Design and the Architecture Masters Preparation programs, formed a team with instructors Eduardo Aquino, Chad Connery, Terri Fuglem and Liane Veness. The team's focus was to collectively design and develop a contribution to the international event on the ice.
>
> Previous Warming Hut proposals have explored an infinite array of imaginative possibilities, without necessarily addressing the essence of the event: a warm hut. The team began with a study of Northern saunas, a typology coherent with the Manitoba's Northern climate and culture. Our inquiry engaged the field of technology, as the intention was to explore innovative, feasible, and sustainable technologies in order to advance an effective inhabitation system fitting Winnipeg's cold temperatures and frozen river surface. The International Institute of Sustainable Development (IISD) played a key collaborative role in this process.
>
> IISD has developed technologies to transform the locally harvested biofuels, such as cattail (Typha) and native prairie grasses, into pellets to burn in a pellet stove. According to IISD, cattail and grasses absorb large amounts of phosphorus, a nutrient that can cause algal blooms when it enters waterways. Harvesting cattail and prairie grasses captures this phosphorus before it can enter urban waterways and Lake Winnipeg—named the most threatened lake in the world in 2013 by the Global Nature Fund. At the same time, cattail harvesting improves the lake's water quality as it produces a renewable energy source in Carbuncle's winter urban setting through a gravity operated pellet burning stove.
>
> The sauna tradition goes back hundreds of years, especially among the culture of Northern peoples. Many sauna typologies have emerged historically, reflecting the culture of the people who used them. Carbuncle works like a sauna, serving as a warming chamber for walkers, skiers and skaters promenading along the Red River/Assiniboine ice trails. The project considers architecture as a social condenser within urban culture, inviting the public to relax within the hotspot of a sauna. The design process involved an intensive design charrette and sessions with the students to identify the very best architectural resolution that would highlight both the character of a Northern Sauna and the biofuel technology. The criteria for the process included an aesthetic referencing Winnipeg's dirty realism and the collision of different vernacular personalities to signify a wide range of positions within the group's diversity. In the end, Carbuncle's triad of asphalt shingles / insulation foam / cedar shingles compressed into a single building, synthesizes the Midwest culture of hybridized domestic architecture.

2.3 Economic Analysis

Harvesting cattails from rural roadside ditches and other grassed waterways for biomass and nutrient management is possible with commercial agricultural equipment, if the environment and conditions are suitable. The cost of harvesting incurred at each site will depend on the field conditions and the type of material harvested. Manitoba Agriculture, Food and Rural Development (MAFRD) publishes the Farm Machinery Custom and Rental Guide that is used to estimate the cost of each field operation. This provides typical costs for equipment operations in normal field conditions. These costs include the rental rate of the equipment, fuel cost, labour rate at CAD 20/hour and a 15 per cent margin on fuel and labour costs. Non-conventional sites such as the Pelly's Lake water retention site and highway ditches do have increased risk of damage to equipment, and owners of equipment will need to be compensated for the additional risk. The costs incurred are listed with the MAFRD rate for normal operations; however, previous research has shown a premium for high-risk locations may be required depending on field conditions.

Table 1. Harvest, baling and forage cost breakdown

Unit Operation	MAFRD Custom Rate (CAD/hr)*	Hours	MAFRD Custom Rate Total (CAD)
Windrower: Self-propelled disc mower conditioner 13–19 ft	CAD 200.88	70	CAD 14,062
Baler: Large square balers 35" x 47" x 98" includes the tractor	CAD 222.81	70	CAD 15,597
Bale mover: 200 hp MFWD tractor	CAD 139.87	30	CAD 4,196
Forage harvester	CAD 222.81	70	CAD 15,597
Total cost			CAD 49,452
Total estimated cost per bale (1,000 square bales)*			CAD 34
Total estimated cost per tonne (600 tonnes)*			CAD 56

**Costs include rental rate, fuel cost, labour rate, and margin on fuel and labour according to the 2014/15 MAFRD Farm Machinery Custom and Rental Rate Guide*

3.0 Land Applying Biomass for Soil Health and Carbon Sequestration

3.1 Overview

Soil is a crucial part of the ecosystem. It holds carbon, water and nutrients in various forms. All three have their own natural cycles where they move in and out of the soil, and these cycles are interlinked. Adding anything new to the soil, like a fertilizer, can affect all three cycles. Harvested cattails (*Typha* spp.) and other mixed grasses harvested from land management activities can be applied back onto cropland as a type of "green manure."

To identify the benefits of land applications, a top-down approach is used, as visually represented in Figure 5. It starts with the broad concept of soil management and keeps getting narrower in scope; each step is elaborated in the next section. An advantage of using this method is that it helps position all aspects of the research in relation to one other.

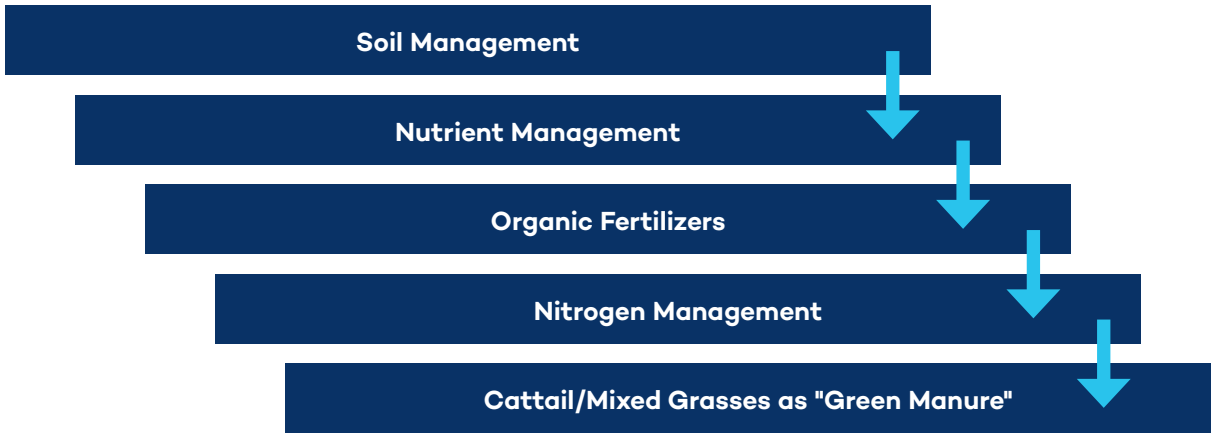

Figure 5. Overview of research methodology

3.2 Impacts of Organic Material on Soil

Soil health is defined as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans" (Natural Resources Conservation Service, 2019). The health of the soil can be managed by a set of broad principles, such as increasing plant diversity, reducing tilling, feeding the soil by growing plants and keeping it covered as much as possible (United States Department of Agriculture, 2019). Collectively these practices are called "**soil health management**." The focus is to maintain the soil composition at a productive and sustainable level. Here, the productivity of the soil is measured through agriculture or crop yield, where yield is the total output of the crops grown per unit of land.

The growth of plants is driven by several factors known as "growth factors": light, heat, mechanical support, water and nutrients. The yield of the land is limited by the factor that is least available (Hilliard & Reedyk, 2015). The two most common limiting factors are water and nutrients. Fertilizers are added if there is a lack of nutrients that is limiting yield.

Optimizing the nutrients added to the soil is done through "**nutrient management**." The use of nutrients must be optimized, as over-usage can lead to excess costs and leakages that affect the environment.[1] There are of two types of fertilizers: organic and inorganic. Plants require nutrients in the inorganic form, and organic fertilizers like manure get converted to inorganic nutrients over time. However, organic fertilizers exist in naturally occurring combinations, and it is difficult to predict its impact on the soil and consequently the yield (Hilliard & Reedyk, 2015). Hence, it is important to understand their composition before being used as a fertilizer.

Looking further, there are 14 essential nutrients that plants obtain from the soil. The most prominent limiting nutrients among these is nitrogen (Hilliard & Reedyk, 2015), and the "Big 3" for plant growth are nitrogen, phosphorus and potassium (The Fertilizer Institute, 2014). Any external fertilizer source or organic compost, such as land applying cattails and mixed grasses, must contribute to these nutrients

Nitrogen management looks to map the amount of nitrogen in the soil and see if it is getting used. It employs the same principles of nutrient management but specified to the chemical nature of nitrogen (Illinois Council on Best Management Practises, 2019). Detailed analysis on how nitrogen addition, losses and impact on the environment has been done by Clark and Beegle (2014).

3.3 Using Cattails as "Green Manure" to Improve Soil Health

Currently, there is no literature that looks exclusively at cattails being used as a fertilizer source. Hence, results have been compiled from analogous research. A Canadian study was conducted to see the nitrogen requirements and its consequent impact on the yield of two prominent crops: canola and wheat (Karamanos, Selles, James, & Stevenson, 2012). It identified that optimal yields of canola required 80 per cent more nitrogen than wheat and that some years have better growing conditions than others, despite the same fertilizer use. Similar mapping exercises are needed to identify suitable crops and farms where cattails can be used as a fertilizer.

In a study conducted in Nebraska, a combination of woody biomass from cedar and manure, both agricultural wastes, were tested as fertilizer for a corn field (Schott, Schmidt, Timmerman, & Smith, 2019). The results did not indicate a significant boost to the yield, but no negative outcomes were observed. The authors concluded that a time frame longer than a year is needed to identify the impacts. Cattails can be considered as a woody biomass and, hence, these lessons show that potentially a longer time frame for research would be needed.

The nature of impacts on soil health can extend beyond looking at the yield. A study by Lim and Matu (2014) compared five agricultural wastes, primarily wet fruit waste, and studied their impacts on soil health. It indicated that certain fruits, like banana, can have a higher potassium release while others, like watermelon, can reduce the soil acidity. This study shows the various factors that need to be considered when measuring the impact of an organic waste-sourced fertilizer.

3.4 Key Takeaways

- Fertilizers can affect the soil through the nutrient cycle. Effective use of fertilizers is studied under nutrient management.
- There is no research on using harvested cattails as organic fertilizers. Comparing results from other studies is limited by the wide range of properties observed among organic fertilizers.
- The requirements of the target crops play a crucial role in determining the effectiveness of the fertilizer. Some crops need higher levels of nitrogen, while in some circumstances the added nutrients barely show any effects.

[1] One example of external environmental effects is the eutrophication observed in Lake Winnipeg.

- A study using woody biomass sourced from cedar indicated that a one-year observation period is insufficient, and a longer duration is needed to study the impacts of the fertilizer on soil health.
- A starting point of further studies would be to match the nutrient profile of cattails to other organic materials. It must be noted that matching the physical properties like moisture content is not sufficiently indicative of the use of cattails as a fertilizer.

3.5 Additional Studies

Other research relevant to the broad goals of the cattail harvesting and the Bioeconomy Project are identified as follows:

- Research looking at new methods of deploying nitrogen fertilizers can broaden the fertilizer's utility. There are newer methods to measure the nitrogen levels and develop site-specific nitrogen management practices. A review of these methods was conducted for Canadian arable lands (Zebarth, Drury, Tremblay, & Cambouris, 2009). One prominent method identified is to use control release fertilizers to match the fertilizer's output to the needs to the crops.
- There is ongoing research on using cattails in wastewater treatment plants through constructed wetlands. Cattail litter has proven to be successful in sulphate and nitrogen removal under different types of water flow in constructed wasteland. Further studies on this topic has been done by Chen et al. (2014) and Wu et al. (2018).
- There are co-benefits to growing cattails, such as reducing lead contamination in the soil (Succuro, 2010). If harvested, there could be negative effects on the local soil health.
- The yield response of cattails to fertilizers has also been studied in detail by Aderinola and Idowu (2014).

4.0 Carbon Market Updates

4.1 The Global Carbon Agreements

Carbon markets have been a central part of the effort to combat the effects of climate change. The first international legislation on creating a carbon market was the Kyoto Protocol in 1997. Since then, the European Union Emissions Trading System and the Clean Development Mechanism (CDM) have carried the idea forward. In the landmark Paris Agreement in 2015, the objectives of such market-based mechanisms were drafted in Article 6 on co-operative action (United Nations Framework Convention on Climate Change, 2015).

In the Paris Agreement, only the principles were agreed upon while the development of a "Rulebook" was left for later. In the agreement, three types of cooperative actions were agreed:

- **Article 6.2. International Transferred Mitigation Outcomes:** This article describes the international transfer of emissions and accounting with respect to meeting the Nationally Determined Contributions.
- **Article 6.4. Mechanism under cooperative approaches:** This article deals with involving non-governmental parties engaged in a carbon emissions market supervised by a body designed by the Conference of the Parties (COP).
- **Article 6.8. Non-market approaches.**

The language of the agreement allows for broad interpretation, which has led to several points of contention in the ensuing international negotiations. This came to a head in the 24th COP in Katowice in November 2018. The debate on the Article 6 panel (International Institute for Sustainable Developement, 2018) covered issues relating to linkages to REDD+[2], share of proceeds to the adaptation funds, linkages to CDM, avoiding double counting under Nationally Determined Contribution targets, reporting practices and setting baselines, among others.

However, at the end of the conference, no consensus was reached among the parties. This was a major shortfall of COP 24, with the International Emissions Trading Association (IETA, 2018) stating, "IETA is deeply disappointed that climate negotiators failed to fulfill their mandate to deliver rules for market cooperation as part of the Paris Agreement 'rule book' at COP 24 in Katowice today."

4.2 North American Carbon Offset Protocols

While the legislation for an international carbon market continues to be discussed, several regional markets have been formed with voluntary participation. These voluntary markets are supported by various registries that issue offset credits that are then sold in the market. A summary of the popular registries, the volume of credits traded and their average price in 2016 is shown in Figure 6, and a direct comparison is made in Table 2.

[2] Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD), is a 2005 program launched to reduce emissions associated with deforestation. It was expanded to REDD+ to include conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (United Nations, 2018).

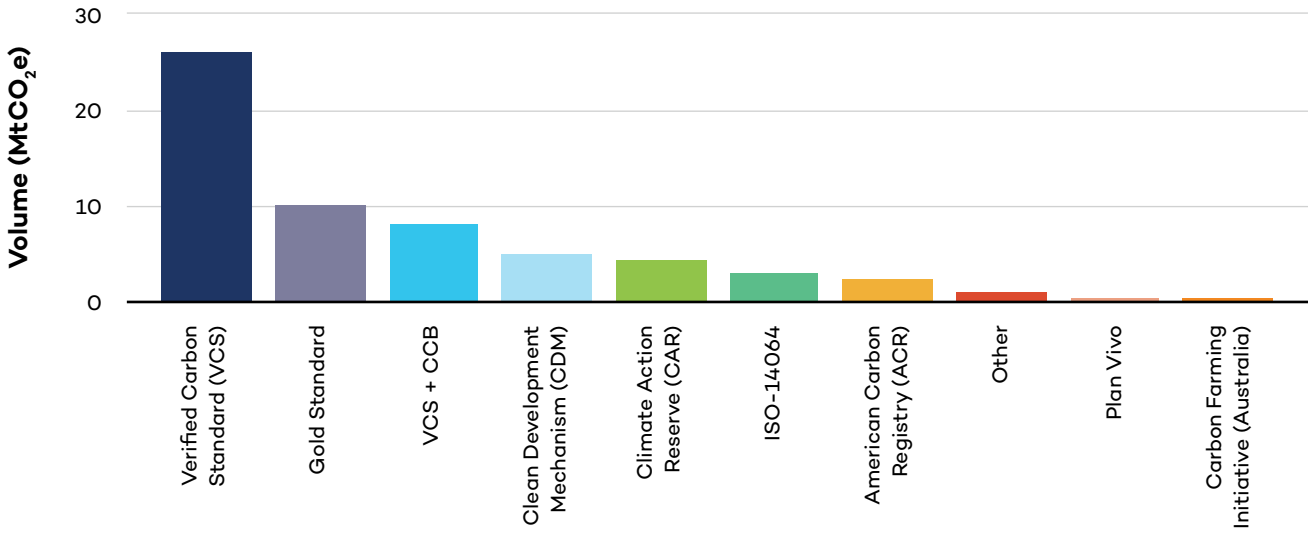

Figure 6. Market volume of carbon credits, 2016

Source: Hamrick & Gallant, 2017.

In North America, two popular carbon market programs are the Western Climate Initiative (WCI) and the Verified Carbon Standard (VCS). In addition to WCI and VCS in North America, another prominent initiative is the Regional Greenhouse Gas Initiative (RGGI), but this one is restricted to the power sector. Given the scope of this research, the focus rests on projects within these programs related to agricultural/land-use carbon offsets.

Table 2. Comparison of credit prices in various mechanisms

Auction	Year	Price (USD/tCO_2e)
WCI-Current	2018 (Average)	14.91
WCI-Future	2018 (Average)	14.82
RGGI	Historic (Highest)	7.50
American Carbon Registry (ACR)	2016 (Average)	4.70
RGGI	2018 (Average)	4.42
Climate Action Reserve (CAR)	2016 (Average)	3.00
VCS	2016 (Average)	2.30
CDM	2016 (Average)	1.60

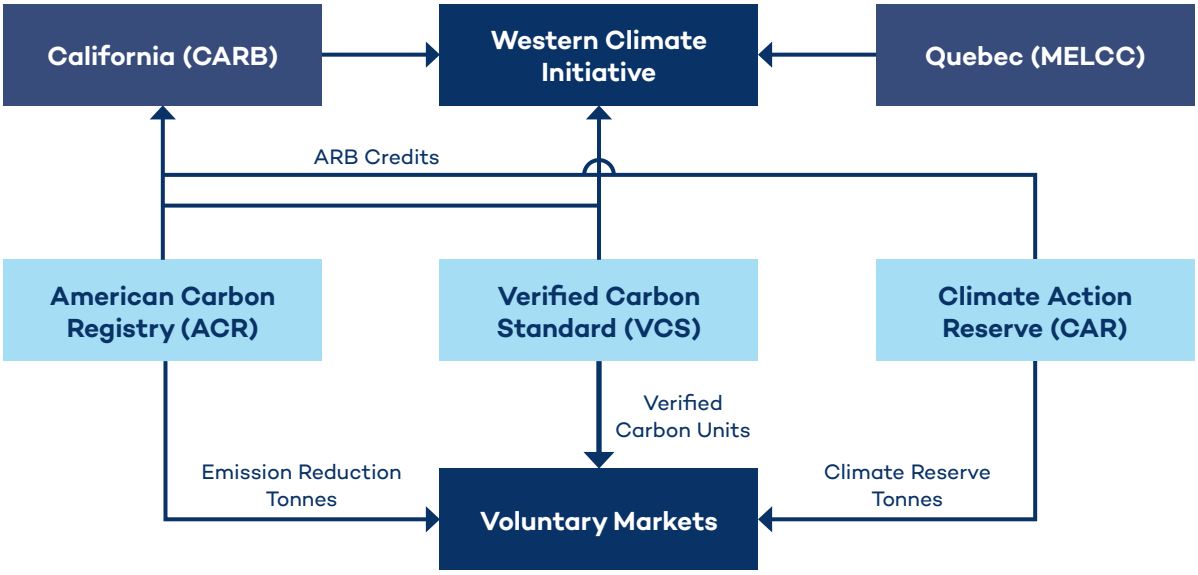

Figure 7. Representation of North American carbon markets

4.2.1 WCI

WCI is a non-profit organization set up to help regional emission trading schemes. When it was designed, five regions—British Columbia, California, Ontario, Quebec and Manitoba—were included. However, only California and Quebec set legislation on emission caps and hence sit on the board of WCI.

The California participation to the WCI is overseen by the California Air Resourced Board (CARB); in Quebec, it is the Ministère l'Environnement et de la Lutte contre les changements climatiques (MELCC). They jointly hold auctions on the sale of offset credits. These auctions are held four times a year in two categories: current and future vintages.[3] The average settlement price in 2018 was USD 14.91 for current vintage and USD 14.82 for future vintage offset credits (California Air Resources Board, 2019). Despite the joint market, the offset protocols and sectoral coverage of the regulations vary by region.

CALIFORNIA

The California carbon market was setup following the Cap-and-Trade Regulation (CATR), which set limits on all utilities. If the regulated entities are unable to meet their emission targets, they can purchase Air Regulation Board (ARB) offset credits from the WCI auctions. Since the program launch in fiscal year 2012/13, the USD 9.47 billion in proceeds to the State of California has been collected in a California Greenhouse Gas Reduction Fund.

Under the CATR, CARB can approve offset registries where projects outside the regulated entities can obtain offset credits, provided they meet the CARB standards. Registries approved by CARB include the ACR, CAR and Verra (formerly Verified Carbon Standard). It must be noted that offset credits under these registries cannot directly be used for compliance with the cap-and-trade program. Registry offset credits must be converted to ARB offset credits to be eligible for use in the cap-and-trade program.[4]

[3] Vintage here refers to the years or period during which the credits are valid.

[4] The conversion of registry-based credits to ARB credits requires further research and is out of the scope of this brief.

The ACR is a non-profit private enterprise that approves offset credits called Emission Reduction Tons (ERTs). In addition to the regulated California market, it supports a voluntary market. The ERTs sold under the voluntary market happens over-the-counter with ACR notified only about the transaction, not the rates. To obtain ERTs, a project must meet the ACR Standard and they must use a sector-specific accounting methodology. The methodology relevant to the scope of this project is Land Use, Land Use Change and Forestry – Improved Forest Management (IFM) for Non-Federal U.S. Forestlands (ACR, 2018). They have 204 accredited projects across the United States categorized into 15 sectors. There are five projects under Agriculture Land Management with a combined 82,516 credits. However, none of them is ARB eligible. The biggest project is Prairie Pothole Avoided Conversion of Grasslands and Shrublands, accounting for 81,917 credits (ACR, 2019).

CAR started as California Climate Action Registry and has been integral to the development of CATR. It functions like ACR: it has an accounting protocol,[5] does third-party auditing and issues credits. It also has a voluntary market. Credits issued for the voluntary market are called Climate Reserve Tonnes and the ones for ARB are called registry offset credits. The CAR has dedicated protocols for Mexico and Ontario as well. The relevant protocols for this project are the *Forest Project Protocol* and *Nitrogen Management Project Protocol* (CAR, 2019b). Among the ARB-compliant projects under Improved Forest Management, 36,668,097 registry offset credits have been issued across 46 projects, all of which are located in the United States (CAR, 2019a).

In addition to the ongoing projects under the registries, CARB has a provision for projects operational between January 1, 2005 and December 31, 2014 to obtain ARB offset credits as Early Action Projects. To be eligible, the projects must have been registered under ACR, CAR or VCS and meet the regulation of CATR. Most of these projects focused on livestock, U.S. forests and ozone-depleting substances; none of them focused on agriculture and land management.

QUEBEC

Quebec set up a cap-and-trade market in 2013 and, one year later, linked it with California's market through the WCI. All proceeds from the market go to the Green Fund, which works on implementing the Climate Change Action Plan. Similar to the CATR, Quebec has regulated companies in the industrial and electricity sector with annual emissions over 25,000 tCO_2e. Companies under this cap can also request to be covered by the market. Also, like Early Action Projects, projects from 2007 that can meet the regulation expectations (i.e., the protocols) can also be accredited.

MELCC lists five types of protocols, but none of them is clearly applicable to the scope of the current project. The focus of these protocols has been on curtailing methane and ozone-depleting substances as opposed to carbon dioxide. However, they are open to independent projects with established protocols as long as they are approved by the WCI.

Unfortunately, the projects aren't explicitly listed and information on non-Quebec, carbon dioxide-based projects is missing. In their register, projects under only two protocols, to a combined 678,183 credits, are listed. These are references to credits issued on January 23, 2019 (MELCC, 2019).

4.2.2 VCS

One of the approved registries under the CARB is VCS. It has been reported separately, as the VCS program claims to be the world's most widely used GHG program, having issued 316,920,305 Verified Carbon Units (VCUs), as of

[5] The terms "methodology" and "protocol" are similar and refer to the accounting framework used to calculate emission offsets. The usage of the terms varies according to the registry, with ACR using methodology and CAR using protocol.

February 2019, each equal to 1 tCO_2e in emission reductions (Verra, 2019f). VCS is overseen by a United States-based non-profit called Verra.[6]

VCS was structured by referencing the CDM. A project is developed under VCS standards and must be independently audited. They must use an approved accounting methodology under which the baseline emissions and the project's reductions are calculated. Following this, the project is issued VCUs, which are then auctioned off. The average market price of a VCU was USD 2.3 in 2016 (Hamrick & Gallant, 2017). However, the price varies significantly based on the project.

Under VCS, the projects are categorized into 15 sectors based on the scope. Under the Agriculture, Forestry and Other Land Use sector, 163 projects were accredited. Among these projects, only 13 were from North America (the United States, Canada and Mexico) with a combined 377,913 tCO_2e being reduced. A prominent project among these 13 is the Darkwoods Forest Carbon Project in British Columbia, which accounts for 124,847 VCUs or 33 per cent of the total VCUs (Verra, 2019e). However, this project has been met with criticism from the Auditor General of British Columbia (Ecosystem Marketplace, 2013). This criticism is indicative of the uncertainties associated with methodologies in the Agriculture, Forestry and Other Land Use sector.

Hence, the need for a robust methodology is crucial for the success for the project. The methodology is fundamentally a framework to quantify the GHG emissions by helping the developers set the boundaries, the baseline emissions and impact of the project. VCS lists its methodologies and also accepts the ones developed by CDM and CAR (Verra, 2019a). The list of methodologies was filtered to match the scope of the cattails project considered, and two were identified. It must be noted that the methodology is subject to change based on the nature of the project.

1. **VM0022 Quantifying N_2O Emission Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction:** This methodology focuses on nitrous oxide (N20) as the primary GHG reduced through optimizing nitrogen fertilizer usage.
2. **VM0007 REDD+ Methodology Framework (REDD-MF), v1.5:** This methodology includes a module for activities to reduce emissions from forest degradation caused by extraction of wood for fuel. This concept is similar to the usage of cattails as a fuel.

In addition to VCS, Verra also manages the Jurisdictional and Nested REDD+ (JNR) and Sustainable Development Verified Impact Standard (SD Vista) programs. JNR is a REDD+ framework, like the VM0007 methodology, that enables the integration of REDD+ projects to VCS. The SD Vista was launched in January 2019 as an accounting framework that considers the sustainable development goals in addition to the emissions. This accreditation is expected to increase the attractiveness of the project and consequently higher rates for the credits issued (Verra, 2019d).

4.2.3 RGGI

In addition to WCI and Verra, North America has another prominent initiative that is restricted to the power sector. The RGGI (pronounced "Reggie") is a cooperative action among nine states in the northeastern United States—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island and Vermont. The goal of the RGGI is to reduce emissions in the power sector, and each of these states has mandated laws to do so. They operate similar to WCI and sell offset credits through auctions.

The total auction proceeds to date are USD 3,075,228,542.17. In the last auction, the clearing price was USD 5.35. The average for 2018 was USD 4.415. The price has not gone above USD 10 since 2008. The states decide how

[6] The name VCS continues to refer to their registry, while the overseeing entity has changed its name to Verra. CARB lists Verra as the approved registry, while Verra themselves label it as VCS.

to use the funds, and they have been invested in energy efficiency, renewable energy and other consumer benefit programs. There are five offset categories for non-power generation emission reduction projects; the one relevant to this project is Forestry or Afforestation. However, this category is not uniformly accepted by all states, as the laws are not harmonized (RGGI, 2019).

4.3 Carbon Offsets in the Manitoba Perspective

Although there is potential for clarity in 2020, the national and international regimes for offsets will remain cloudy in 2019 as a number of dynamics shift, including:

- A Canadian federal election will decide the fate of national carbon pricing in Canada. If the current Liberal government falls, it is highly unlikely we will see a national carbon price or a national GHG offset system. However, if this is the case, it is not necessarily the end of potential for offsets. If a Conservative government looks at alternate approaches, they could go back to equivalency measures that the Harper government adopted, with regulated GHG emission reductions as a backstop instead of a national carbon price. Through provincial/territorial equivalency measures, provinces could adopt their own systems for emission reductions, which could allow for a vibrant voluntary market on a national level (e.g., if the oilsands sector in Alberta were allowed to use land-use offsets from Manitoba to meet its targets) or provincial compliance systems like we see now in Quebec. If the Liberal government wins the 2019 election, a national offset system is more likely but is probably something that will take until the middle of their next term to truly take shape, including methodologies (see below on output-based pricing). In short, the potential offsets post-2019 are uncertain; however, at the very least, a voluntary market will remain viable.
- On the international level, COP 25 will be telling. If the development of a national market is truly only delayed, COP 25 in Santiago will offer a lot of direction on what that system will look like going forward and how Canada will interact with it. However, if the sticking points cannot be resolved, it is likely that this issue could drag on for multiple years. As a result, looking to the international system in 2019 will either present a clear pathway forward or present an extremely complicated map. By the end of COP 25, we will know which it is.
- Within Manitoba, a provincial carbon price is unlikely, but if the Liberal government wins the next election, the federal backstop will apply in Manitoba, and it will include a system for large emitters. This system is referred to as an "output-based pricing system." If a particular facility exceeds its targeted emissions allocation, it will be allowed to use eligible carbon offset credits to meet its targets as a lower-cost option for compliance. This allows for voluntary offset credits to be used as part of the federal pricing system, which Manitoba will be subject to, providing the current federal government remains in place.
- The provincial election in Alberta will also be indicative of the future of GHG offsets. Alberta is predicted to be a major demand source for GHG offset credits going forward, but that could change. The provincial system for GHG offsets could be dismantled, the federal backstop could end up in place, or we could see the federal government back off carbon pricing entirely. While the federal election will determine the fate of national carbon pricing, the provincial election in Alberta will dictate what happens in one of the major potential demand hubs for offset credits going forward.

With these dynamics, the picture of the potential of GHG offset demand in Canada is uncertain in 2019, but there is a lot of potential for clarity by the end of the year.

With clear direction on potential methodologies, the path gets easier. And utilizing voluntary system methodologies provides a good safety net if compliance systems fail to emerge. Also, noting that the VCS alone generated USD 76 million in revenue in 2016, there is also a robust trade in voluntary credits that is indicating long-term stability for voluntary credit demand. While we wait out 2019, it is reassuring that voluntary markets remain strong in the meantime.

5.0 Carbon Market Verification Methodologies

5.1 Finding a Verification Method for Watershed Harvest Management

Various carbon market verification methodologies were assessed to identify those that match best with the current work on unconventional biomass use (i.e., cattail and mixed grasses) in the context of the Lake Winnipeg Watershed in Manitoba.

An initial scan of verification methodologies focused on:

- Replacing coal in district heating systems as a biomass feedstock
- Collecting and processing ash as fertilizer to replace synthetic nitrogen fertilizers
- Diverting agricultural waste streams to prevent eutrophication
- Reducing nitrogen runoff to prevent eutrophication

Project descriptions of verification methodologies vary significantly and identifying a comparable project is difficult, although attempts have been made. Additionally, some registries list projects that were developed using methodologies for a different registry/market, the most prominent one being the CDM (United Nations Framework Convention on Climate Change, 2019).

5.2 What is a Methodology/Protocol?

A methodology or protocol[7] refers to a framework that can be used to measure the emission reductions of a project. They can be complex frameworks designed to cover a range of activities while also maintaining accountability and transparency. They are usually designed by research institutions and undergo several rounds of peer review. An example decision framework is the decision tree from REDD in Figure 8. A typical methodology contains the following elements:

- Applicability conditions: This can be represented through a flow chart, checklist or text where the planned project needs to meet functional criteria (i.e., Figure 8).
- Project boundary: Spatial and temporal boundaries as well as the GHGs considered.
- Calculations for baseline: Equations, assumptions and data sources required for calculating the baseline emissions.
- Calculation for project additionality: Equations, assumptions and data sources required for calculating the impact of the project.
- Monitoring parameters: Data and reporting needed to monitor the progress of the project.

While these methodologies are designed to cover a range of projects, often they are amended to better match the project design. This is done through the third-party accounting, and some registries publish the relevant reports.

[7] The terminology varies based on the registry or market. Methodology is primarily used in this report.

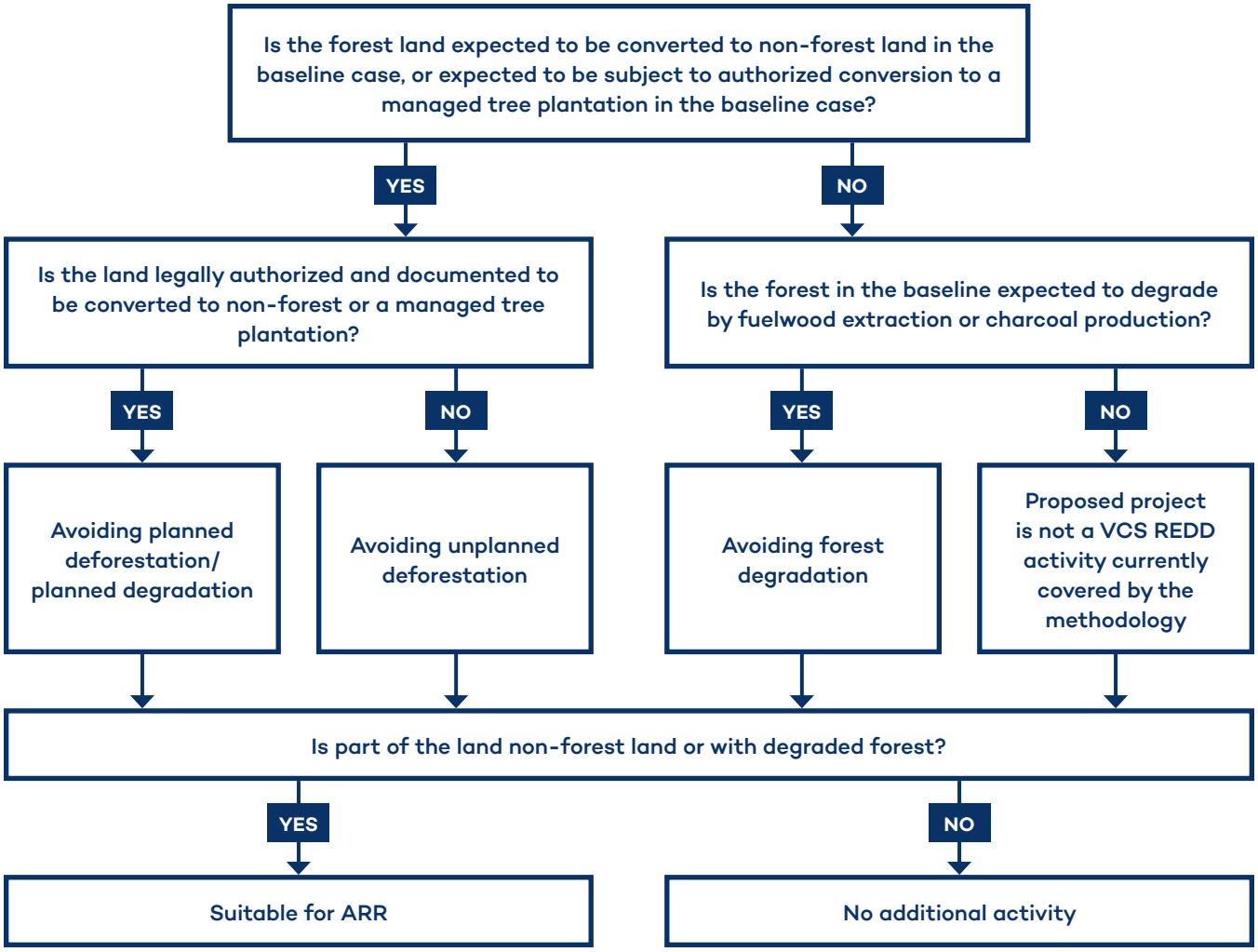

Figure 8. An example decision framework: The decision tree for determining REDD Project Activity type

Source: VCS, 2015.

5.3 Reviewed Verification Methodologies

The following verification methodologies have been identified as potentially applicable for a project focused on utilizing harvested cattail biomass as an energy feedstock, as well as looking at nitrogen reduction options from the harvest and use of cattail biomass. We restrict the review to offset standards that are active in North America.

VM0022 Quantifying N_2O Emissions Reductions in Agricultural Crops through Nitrogen Fertilizer Rate Reduction

- This methodology has been developed by VCS (2013).
- The eligible projects are expected to reduce emissions from nitrous oxide by reducing the fertilizer used in the agricultural land. It must be noted that this does not cover projects that displace conventional synthetic nitrogen fertilizers as has been done with the cattails project. However, if synthetic nitrogen fertilizer is reduced in part by using cattail biomass, this could be applicable as a methodology.

- A constraint to this methodology is that there must be no drop in yield, and it is applicable exclusively to projects in the United States in its current form.
- There are two types of emissions—direct and indirect, depending on where the emissions occur within the project boundaries. The indirect method includes leaching and runoff of nitrogen. However, eutrophication reduction is not directly considered.
- No projects were identified to be using this methodology. The only projects relevant to nitrous oxide reduction found were in the chemical industry, which in turn used methodologies developed under CDM (Verra, 2019).

VM0007 REDD+ Methodology Framework (REDD-MF), v1.5

- This methodology has been developed by VCS (2015).
- The projects are expected to reduce emissions by avoiding planned and unplanned deforestation (REDD); afforestation, reforestation and revegetation; or wetland/peatland conservation. The applicability is represented through the decision tree in Figure 8.
- This is a broad methodology with 23 interlinked modules. Depending on the project, calculations and reporting must be done using relevant modules. Common requirements include system boundaries and the carbon stocks considered as a part of the calculations.
- Module VMD0008 on degradation caused by extraction of wood considers the use of biomass for fuel as fuelwood or charcoal. However, the baseline case here is a non-renewable form of fuelwood collection that is reduced, as opposed to replacement of coal as is the case with the current cattail project.
- In current structure, this methodology does not directly apply to the cattail project unless there is an improvement of wetland or peatland due to cattail growth.
- The majority of the projects using the same or equivalent methodology focus on forested lands. One comparable example is the Sustainable Climate-Friendly Coffee project in Mexico, which uses a CDM methodology for a small-scale sustainable land management practice (Verra, 2019c).

Livestock: Changes in Fertilizer Management

- This methodology is still categorized as "in development" by the ACR, despite reporting from 2014 (ACR, 2014).
- This is being developed to cover projects outside the scope of the established methodology, Reduced Use of Nitrogen Fertilizer on Agricultural Crops, which considers reduction of fertilizers exclusively (ACR, 2012). This methodology is built on the CDM methodology, AR-ACM0001 Afforestation and Reforestation of Degraded Land.
- Under the ACR project design, credit stacking can be done (i.e., ACR credits for emissions and some other credits for ancillary benefits such as improving water quality).
- The methodology is similar to VM0022, and there is a constraint that yield must not drop. In addition, the calculation framework is complex, requiring the use of Monte Carlo simulations for baseline and project forecasts.
- No projects were identified due to an absence of clear tagging of methodologies or project descriptions.

Nitrogen Management Project Protocol

- This methodology (protocol) has been developed by CAR (2018).
- The design of the protocol is similar to Reduced Use of Nitrogen Fertilizer on Agricultural Crops (ACR, 2012) and VM0022 (VCS, 2013). Projects are expected to reduce nitrogen fertilizer usage.

- The protocol is applicable to selected crops located within the United States alone. Conditions on drop in yield are also imposed.
- No projects were identified due to the absence of clear tagging of methodologies or project descriptions.

Quantification Protocol for Biofuel Production and Usage (version 2.0)

- This methodology (protocol) has been developed for the Alberta Emission Offset System (Alberta Government, 2014a).
- The protocol scope covers only the production of biofuels and not biomass; however, several end uses of biofuels, including transport and power generation, have been included.
- The protocol limits production and usage of biofuels only in Alberta while the biomass feedstock can be from anywhere in North America. Co-products of other production facilities are excluded. Cattails have not been explicitly stated as an eligible feedstock, but allowance is given for "municipal waste materials diverted from landfill that complies with the Municipal Solid Waste Guideline" (Alberta Government, 2014a).
- The GHGs considered are carbon dioxide, methane and nitrous oxide. Further site-specific emission factors can be used if supporting calculations are provided.
- There are three projects under this protocol, all which have been retired. The combined lifetime emission reduction was 608,760 tCO_2e (Alberta Carbon Registries, 2019). Two of the projects produce ethanol from high-starch grains, while the third uses beef tallow to make biodiesel.

Energy Generation from the Combustion of Biomass Waste (version 2.2)

- This methodology (protocol) has been developed for the Alberta Emission Offset System (Alberta Government, 2018).
- This protocol differs from the previous one in that direct conversion of biomass waste to energy is done as opposed to the production of biofuels. This distinction has also been stated in the documentation.
- The list of biomass waste eligible has been categorized explicitly, but the cattails project doesn't fit any of the categories perfectly. Close matches include debris from forest harvesting, agricultural crop residue and municipal solid waste. Further, purpose-grown energy crops are ineligible.
- This protocol is a close match to the existing use of cattails for displacing coal. However, under Alberta laws, production of thermal energy will be included in the calculations, but offsets will not be awarded. The reasoning is that the power producer makes gains from a reduced carbon levy at the point of generation.
- The GHGs considered are carbon dioxide, methane and nitrous oxide. Details on project boundaries and assumptions have been given in the protocol document.
- There are three projects, all of them active, under this protocol with a combined lifetime emission reduction of 512,064 tCO_2e (Alberta Carbon Registries, 2019). The Tolko Slave Lake Biomass Offset Project is the biggest and uses forest waste biomass as a fuel. Its potential annual emission reduction is 25,000 tCO_2e (Tolko Industries, 2015). The other projects use bovine waste and sawmill waste as feedstock.

5.4 Applicability to Watershed Harvest Management

Based on the study of the methodologies, the following are the key takeaways that must be considered for the next stage of the research:

- The methodologies reviewed have been predominantly used for improved use of forested land and reducing the use of synthetic nitrogen fertilizers. Further, they have been restricted to projects in the United States.
- A limited number of comparable projects exists. Going ahead, a better understanding on project boundaries and co-benefits is needed to make comparisons.
- Potential co-benefits of the current project with regards to wetland restoration must be studied to take advantage of reviewed methodologies on REDD.
- The nature of the fertilizers obtained from cattail ash treatment must be reviewed and compared with synthetic fertilizers for nitrous oxide release.
- Potential for stacking credits must be considered in the case of multiple benefits beyond GHG emission reductions.

6.0 References

Aderinola, O., & Idowu, A. A. (2014). A study of the Agronomic parameters of Dominican Cattail (*Typha domingensis*) as influenced by type of fertilizer application. *Journal of Agriculture and Veterinary Science*. Retrieved from http://iosrjournals.org/iosr-javs/papers/vol7-issue7/Version-4/I07743740.pdf

Alberta Carbon Registries. (2019, March 21). *Alberta Emissions Offset Registry Listings*. Retrieved from https://www.csaregistries.ca/albertacarbonregistries/eor_listing.cfm?advanced=yes#results

Alberta Government. (2014a). *Quantification protocol for biofuel production and usage*. Retrieved from https://open.alberta.ca/dataset/a2c40c67-501a-4257-b5b5-40464ab70b46/resource/72334c7c-efc5-4adf-87b3-9443a35d4147/download/4072080-2014-10-quantification-protocol-biofuel-production-usage-version-2.0.pdf

Alberta Government. (2018). *Energy generation from the combustion of biomass waste*. Retrieved from https://open.alberta.ca/dataset/882aa4e1-9358-4a98-a633-9435b2a49830/resource/501c00bd-4385-4c45-94bd-bc4a0efa0ee0/download

American Carbon Registry. (2012). *Methodology for quantifying nitrous oxide emissions reductions from reduced use of nitrogen fertilizer on agricultural crops*. Retrieved from https://americancarbonregistry.org/carbon-accounting/standards-methodologies/emissions-reductions-through-reduced-use-of-nitrogen-fertilizer-on-agricultural-crops/msu-epri-methodology-acr-v1-0_final.pdf

American Carbon Registry. (2014). *The American Carbon Registry® Methodology for N2O Emission Reductions through Changes in Fertilizer Management*. Retrieved from https://americancarbonregistry.org/carbon-accounting/standards-methodologies/emissions-reductions-through-changes-in-fertilizer-management/acr-methodology-for-n2o-emission-reductions-through-changes-in-fertilizer-management_v2-0-final.pdf

American Carbon Registry. (2018). *The American Carbon Registry Standard*. Retrieved from https://americancarbonregistry.org/carbon-accounting/standards-methodologies/american-carbon-registry-standard/acr-standard-v5-1-july-2018.pdf

American Carbon Registry. (2019, March 1). Project directory. Retrieved from https://acr2.apx.com/myModule/rpt/myrpt.asp?r=111

California Air Resources Board. (2019, March 1). Archived auction information and results. Retrieved from https://ww3.arb.ca.gov/cc/capandtrade/auction/auction.htm

Chen, Y., Wen, Y., Zhou, J., Tang, Z., Li, L., Zhou, Q., & Vymazal, J. (2014). Effects of cattail biomass on sulfate removal and carbon sources competition in subsurface-flow constructed wetlands treating secondary effluent. *Water Research, 59*, 1–10.

Clark, K., & Beegle, D. (2014). *Nutrient management to improve nitrogen use efficiency and reduce environmental losses*. Pennsylvania State University. Retrieved from https://extension.psu.edu/programs/nutrient-management/educational/soil-fertility/nutrient-management-to-improve-nitrogen-use-efficiency-and-reduce-environmental-losses/extension_publication_file

Climate Action Reserve. (2018). Nitrogen Management Project Protocol. Retrieved from http://www.climateactionreserve.org/how/protocols/nitrogen-management/

Climate Action Reserve. (2019a, March 1). Protocols. Retrieved from http://www.climateactionreserve.org/how/protocols/

Climate Action Reserve. (2019b, March 1). Projects. Retrieved from http://www.climateactionreserve.org/how/projects/

Ecosystem Marketplace. (2013, April 4). This week in forest carbon: Auditor General condemns darkwoods. Retrieved from http://www.ecosystemmarketplace.com/articles/this-week-in-forest-carbon-auditor-general-condemns-darkwoods/

European Commission. (2012). *Innovating for sustainable growth: A bioeconomy for Europe*. Retrieved from https://publications.europa.eu/en/publication-detail/-/publication/1f0d8515-8dc0-4435-ba53-9570e47dbd51

European Commission. (2019). *Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the implementation of the Circular Economy Action Plan* (COM/2019/190final). Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0190

Faculty of Architecture. (1017). *Carbunckle: A warming hut*. Retrieved from https://umanitoba.ca/faculties/architecture/media/_Carbuncle_Warming_Hut_2017.pdf

Government of Canada. (2019). Canada's Climate Plan. Retrieved from https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan.html

Government of Manitoba. (2019). Manitoba's Made-in-Manitoba Climate and Green Plan. Retrieved from https://www.gov.mb.ca/climateandgreenplan/index.html

Grosshans, R. (2018, December 14). Canada should copy Europe when it comes to the bioeconomy. Retrieved from https://www.iisd.org/blog/canada-europe-bioeconomy

Grosshans, R. (2018, Decembe 12). #Canada should take a leaf out of Europe's books when it comes to #SustainableEnergy future. *EU Reporter*. Retrieved from https://www.eureporter.co/environment/2018/12/12/canada-should-take-a-leaf-out-of-europes-books-when-it-comes-to-sustainableenergy-future/

Hamrick, K., & Gallant, M. (2017). *Unlocking potential: State of the voluntary carbon markets 2017*. Ecosystem Marketplace. Retrieved from https://www.cbd.int/financial/2017docs/carbonmarket2017.pdf

Hilliard, C., & Reedyk, S. (2015). *Nutrient management planning*. Agriculture and Agri-Food Canada. Retrieved from http://www.agr.gc.ca/eng/science-and-innovation/agricultural-practices/soil-and-land/soil-nutrients/nutrient-management-planning/?id=1187355760327

Illinois Council on Best Management Practices. (2019). Nitrogen management. Retrieved from http://www.illinoiscbmp.org/Practices/Nitrogen-Management/

International Emissions Trading Association. (2018). COP24 fails to deliver on mandate for carbon market cooperation - IETA. Retrieved from https://www.ieta.org/page-18192/6961313

International Institute for Sustainable Developement. (2018, December 18). *Earth Negotiations Bulletin: COP 24 Final*. Katowice. Retrieved from http://enb.iisd.org/download/pdf/enb12747e.pdf

Karamanos, R. E., Selles, F., James, D. C., & Stevenson, F. C. (2012). Nitrogen management of fallow crops in Canadian prairie soils. *Canadian Journal of Plant Science, 92*(7), 1389–1401. Retrieved from https://www.nrcresearchpress.com/doi/pdf/10.4141/cjps2012-031

Lim, S.-F., & Matu, S. U. (2014). Utilization of agro-wastes to produce biofertilizer. *International Journal of Energy and Environmental Engineering, 6*(1), 31–25. Retrieved from https://link.springer.com/article/10.1007/s40095-014-0147-8

Ministère l'Environnement et de la Lutte contre les changements climatiques. (2019, March 1). Register of offset credit projects. Retrieved from http://www.environnement.gouv.qc.ca/changements/carbone/credits-compensatoires/registre_creditscompensatoires-en.htm

Natural Resources Conservation Service. (2019, May 1). Soil health. Retrieved from https://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/

Regional Greenhouse Gas Initiative. (2019, March 5). Forestry and afforestation. Retrieved from https://www.rggi.org/allowance-tracking/offsets/offset-categories/forestry-afforestation

Schott, L., Schmidt, A., Timmerman, A., & Smith, A. (2019). *Utilization of woody biomass and manure as agricultural soil amendments in Nebraska*. Retrieved from https://lpelc.org/utilization-of-woody-biomass-and-manure-as-agricultural-soil-amendments-in-nebraska/

Succuro, J. S. (2010). The effectiveness of using Typha latifolia (broadleaf cattail) for phytoremediation of increased levels of lead-contamination in soil. Humboldt Digital Scholar. Retrieved from http://humboldt-dspace.calstate.edu/handle/2148/587

The Fertilizer Institute. (2014). Fertilizer 101: The Big 3 – Nitrogen, phosphorus and potassium. Retrieved from https://www.tfi.org/the-feed/fertilizer-101-big-3-nitrogen-phosphorus-and-potassium

Tolko Industries. (2015). *Tolko Slave Lake Biomass Offset Project*. Retrieved from https://www.csaregistries.ca/files/projects/9963_2876_AEOR_OffsetProjectPlan_20150101_20221231.pdf

United Nations. (2018, February 08). About REDD+. Retrieved from https://www.unredd.net/about/what-is-redd-plus.html

United Nations Framework Convention on Climate Change. (2015). *Paris Agreement*. Retrieved from https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

United Nations Framework Convention on Climate Change. (2019, March 15). *CDM Methodologies*. Retrieved from https://cdm.unfccc.int/methodologies/index.html

United States Department of Agriculture. (2019). *Soil health: Key points*. Retrieved from https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1082147.pdf

Verified Carbon Standard. (2013). *Approved VCS methodology VM0022: Quantifying N_2O Emissions Reductions in Agricultural Crops Through Nitrogen Fertilizer Rate Reduction* (V1.1, Sectoral scope 14). Retrieved from https://verra.org/wp-content/uploads/2018/03/VM0022-v1.1-Methodology-for-N-Fertilizer-Rate-Reduction.pdf

Verified Carbon Standard. (2015). *VM0007: REDD+ Methodology Framework (REDD-MF)*. Verra. Retrieved from https://verra.org/wp-content/uploads/2017/10/VM0007v1.5.pdf

Verra. (2019a). Methodologies. Retrieved from https://verra.org/methodologies/

Verra. (2019b, March 15). Project database: N2O abatement in MP Nitric Acid plants at Rashtriya Chemicals & Fertilizers Limited, India. Retrieved from https://www.vcsprojectdatabase.org/#/project_details/567

Verra. (2019c, March 15). Project database: Sustainable Climate-Friendly Coffee. Retrieved from https://www.vcsprojectdatabase.org/#/project_details/1414

Verra. (2019d, March 8). *Sustainable Development Verified Impact Standard: Rules & regulations*. Retrieved from https://verra.org/project/sd-vista/rules-requirements/

Verra. (2019e, February 19). VCS Project Database. Retrieved from https://www.vcsprojectdatabase.org/#/vcs

Verra. (2019f, February 19). Verified Carbon Standard. Retrieved from https://verra.org/project/vcs-program/

Wu, S., Gao, L., Gu, J., Zhou, W., Fan, C., He, S., . . . Wang, Z. (2018). Enhancement of nitrogen removal via addition of cattail litter in surface flow constructed wetland. *Journal of Cleaner Production, 204.*

Zebarth, B. J., Drury, C. F., Tremblay, N., & Cambouris, A. N. (2009). Opportunities for improved fertilizer nitrogen management in production of arable crops in eastern Canada: A review. *Canadian Journal of Soil Science, 89*(2): 113–132. Retrieved from https://www.nrcresearchpress.com/doi/10.4141/CJSS07102#.XMKfliNXo2w

Zubrycki, K. & R. Grosshans. (2013). Cattails for clean community waterways (IISD Video). Winnipeg: International Institute for Sustainable Development. Retrieved from http://www.iisd.org/library/cattails-clean-community-waterways

Published by the International Institute for Sustainable Development.

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