Cost Assessment for Cornstalk Supply Chain for Bioprocessing Purposes

Addendum to September 2015 Report

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Executive Summary

Much has been learned with respect to harvesting cornstalks for bioprocessing purposes in Ontario. Previous work completed in 2013 determined that sufficient volumes of cornstalks are available in southwestern Ontario to potentially supply a bioprocessing plant.

A follow-up to that initial work resulted in a report prepared in September 2015 that provided information about harvest costs in Ontario and included a ramp-up phase in the financial model for the biomass producer co-operative. This report provides additional information that has been learned since the September 2015 report.

In particular, harvesting corn stover in a sustainable way was identified as a risk early on in this project. The use of satellite imaging in 2016 was able to provide a link between Ontario grain corn yield and corn stover yield while the crop was still growing. This information is beneficial to corn stover users such as a bioprocessing plant as it provides validation of supply and it assures the government and the public that harvest can be undertaken sustainably. As well, ongoing research at the field level comparing different soil types, tillage and corn stover removal rates will show the effect on corn grain yield and GHG emissions over time. Sustainability of harvest is something that will need to continue being monitored and proven in order to satisfy producer concerns.

Considerable literature is available in the US with respect to corn stover harvest however understanding some of the terminology (e.g. bale weights, harvest costs, etc.) in Canadian dollars and metric weights was lacking. As individuals become more aware of the possibility of harvesting cornstalks in Ontario there have been questions about calculating the following: amount of stover removal; stover havest costs; value of nutrients removed; and so on. To assist with answering these questions a spreadsheet was developed and is available on the OFA website.

Some of the risks identified previously for this project remain. These include exchange rate, the price of sugar, weather conditions at time of harvest and length of harvest, and markets for the cellulosic sugar and co-products. Satellite imaging will be helpful in determining efficient harvest and logistic strategies that can help mitigate some of the harvest risk.

Finding high value markets for the cellulosic sugar and co-products is critical. This will require technologies that will produce high purity, consistent products for target markets. Research is ongoing globally to develop technologies for higher value C5 and lignin co-product streams but doing so at similar prices and with the same or better properties (e.g. strength, temperature rating) of existing petroleum-based products is currently a challenge.

Momentum is building to move towards a more biobased economy in order to improve upon current products and to meet government policy intentions with respect to GHG reduction targets. Corn producers may benefit by moving up the value chain and participating in cellulosic sugar production for use in biobased products.

Table of Contents

List of Tables

List of Figures

1.0 Introduction

This is the final report of a project undertaken to investigate establishing a cornstalk supply chain to be used for bioprocessing in southwestern Ontario. The report will begin with some background on the project and then move into what has occurred since September 2015 when the last report was completed and discuss the financial model with respect to current sugar prices and the role of co-products.

1.1 Background

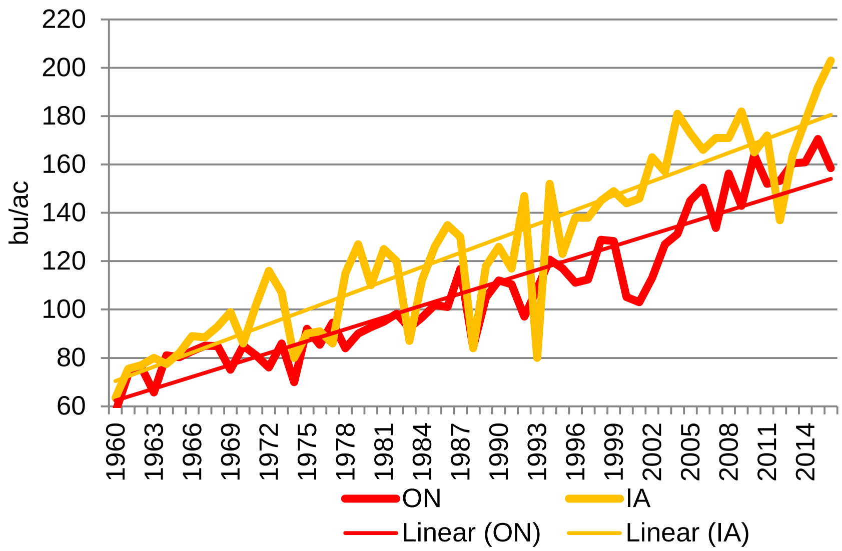
An initial project was completed in 2013 to develop a business case for cornstalks to bioprocessing in southwestern Ontario (Duffy & Marchand, 2013). That project evaluated potential pricing methods and business models based on a venture converting 250,000 dry tonnes of cornstalks annually into cellulosic sugar. The project found that a bioprocessing co-op structure was the preferred model as it involves all members of the value chain and reduces risk. Corn stover producers would sell stover and potentially benefit from co-op dividends. The stover price would be based on sugar prices and sugar yields at the plant. The bioprocessor would benefit from the ability to access a secure supply of stover at less variable prices.

Much of the research was based on feedback from industry stakeholders including corn producers and work done on corn stover harvest in Iowa. The 2013 report found many areas where further research was needed. These included understanding cornstalk harvest and costs under Ontario conditions, educating producers and the public, selecting a technology that could convert cornstalks into cellulosic sugars, improving supply system efficiencies and constructing a plant. A report was undertaken in September 2015 (Marchand) that provided more accurate information with respect to Ontario harvest costs. This final report is an addendum to the 2015 report and includes a discussion of activities undertaken and knowledge learned since 2015.

1.2 Cornstalk Removal

As corn yields have increased over time, the amount of cornstalks has increased as well. Figure 1 shows that in Ontario and Iowa corn yields have been trending up. Anecdotal evidence suggests that some of the newer corn hybrids take longer to break down in the field and farmers are seeking ways to manage the increased amount of cornstalks left after the grain is harvested.

Figure 1 Ontario and Iowa Average Corn Yields Over Time (bu/ac)



Source: Statistics Canada; USDA, NASS

The initial study, Development of a Business Case for a Cornstalks to Bioprocessing Venture (Duffy & Marchand, 2013), identified sufficient cornstalks in the four county region of Lambton, Huron, Chatham-Kent and Middlesex to supply 250,000 dry tonnes of cornstalks annually to a cellulosic sugar plant. Table 1 provides crop insured corn acres in the four counties broken down into 10 bushel/acre increments. Acres yielding less than 150 bushels/acre were not included because this is the minimum acceptable yield for cornstalk removal to be sustainable (as discussed in Duffy & Marchand, 2013 and Marchand, 2015). Using average estimates of sustainable corn stover removal for the four county region (Oo et al., 2012) over 570,000 tonnes of corn stover were available in 2016.

Table 1 Corn Acres by Average Yield Category for Four County Region

	2008	2009	2010	2011	2012	2013	2014	2015	2016
150-159 bu/ac	33,623	76,975	50,295	42,453	37,104	45,273	55,956	31,397	28,076
160-169	52,731	69,602	61,660	79,082	66,210	69,226	76,751	58,049	36,526
170-179	50,497	61,889	88,071	90,721	66,473	80,012	91,382	70,417	69,030
>=180	248,197	123,329	204,139	221,073	308,880	277,207	197,272	294,212	355,300
# of acres >=150	385,048	331,795	404,165	433,329	478,667	471,718	421,361	454,075	488,932

Source: Agricorp. Data represents the acres that premiums are paid on.

As corn yields have trended higher over time there is interest in ways to handle the extra amount of cornstalks. The significant volume of corn stover in southwestern Ontario lends itself to the possibility of supplying a bioprocessing facility.

2.0 An Update of Information and Activities Since 2015

In the US there have been several reports prepared over time discussing the availability of biomass for bioenergy and bioproducts purposes. The most recent report, the US Billion-Ton Report (US DOE, 2016), reiterates that supplying a commercial plant requires reducing risk and encouraging producer participation. Some of the potential barriers the report cited were: efficiency of harvesting equipment; moisture content of the stover/biomass; quality of stover/biomass; and cost of transportation (US DOE, 2016). It is suggested that to be more cost effective and efficient in supplying biorefineries that it is necessary to preprocess biomass (US DOE, 2016; Kurian et al, 2013). This stage transforms the bulky stover/biomass into a commodity that is also more consistent (Kurian et al, 2013).

Cellulosic ethanol plants in the US have been used throughout these projects as examples of large-scale corn stover harvest. For example, the POET-DSM plant in Iowa requires about 285,000 dry tons of cornstalks annually. The methods and equipment used for harvest, logistics, staging, and pricing methodologies were reviewed for applicability under Ontario conditions. There were originally three large cellulosic ethanol plants – POET-DSM (Iowa), DuPont (Iowa), and Abengoa (Kansas) – however the Abengoa plant closed due to bankruptcy of the parent company. It appears that the Abengoa plant was sold to Synata Bio but it's not currently producing cellulosic ethanol (RFA).

The two remaining plants, POET-DSM and DuPont, were commissioned in 2014 and 2015 respectively yet it's unclear if they are operating at full capacity at this time (RFA). There could be various reasons for the slower than expected move to full operating capacity. For example, running corn stover through any process is very hard on equipment because it may include stones or dirt that are picked up during harvest. This can result in breakdowns at the plant and may result in the need for additional steps such as including a preprocessing/washing stage that would remove stones and dirt. Similar difficulties were initially experienced with cornstalk baling and the need for balers that could withstand the tough stalk material as well as dirt and stones.

Something else that has been observed in the US is the potential for fires at corn stover storage areas. In 2016 there were two fires at DuPont corn stover storage areas caused by lightning. This risk could negatively impact plant targets if there is no strategy in place to mitigate this risk by maintaining extra corn stover inventory, understanding how to locate and store bales to minimize losses due to fire, and understanding how to put out fires quickly in order to salvage some of the stored bales.

The Cellulosic Sugar Producers Co-operative (CSPC) is currently looking to sign corn producers in southwestern Ontario to invest in the co-op and commit to providing corn stover and wheat straw for bioprocessing. This is a unique model and is one of the models described in the 2013 Report. This co-op looks to secure between 40,000 to 55,000 acres (75,000 tonnes of stover) and some wheat straw acreage to supply a biochemical plant that will produce 27,000 tonnes of cellulosic sugar annually. The co-op will have a 40% equity stake in the plant. Stover producers can receive income from the sale of corn stover (or wheat straw) to the co-op and potentially through dividends of the sugar plant.

Since 2015 work has continued in Ontario in order to address some of the risks that were identified in previous work. Two key risks relate to the following: soil productivity and sustainability of cornstalk harvest; and identifying higher value markets for C5 sugar and lignin co-products.

2.1 Sustainability of Corn Stover Removal

There are different aspects being researched and monitored with respect to sustainability of corn stover harvest. For example, in 2016 in Ontario satellite imagery was used to estimate corn yield (and therefore cornstalk yield) prior to harvest. Imaging was done every three weeks during the growing season to monitor changes that occurred in the crop to assist in predicting yields. Going forward this will help ensure sustainable cornstalk removal because high yielding fields can be identified prior to harvest. From a bioprocessing co-op's perspective this would provide a better understanding of supply availability and assist with corn stover harvest logistics and the timely movement of harvest crews from field to field.

Other research has used modelling to show that there should be protocols for stover removal (Gan et al., 2015) so that the productive capability of the soil is not degraded. These protocols are based on soil type and management practices (such as type of tillage) (Gan et al., 2015). Potential ventures involving corn stover removal would be recommended to consider implementing these protocols in order to address sustainability concerns of producers and the public.

Further, Drury et al. (2016) is conducting corn yield and GHG emissions research relative to corn stover removal rates. The research compares different tillage systems, soil types and amount of stover removed. This research is ongoing and will contribute greatly to understanding how much corn stover can be removed without negatively impacting the long-term productivity of the soil.

As Ontario corn producers are becoming more aware of potential opportunities with respect to cornstalk removal they are seeking information on how to calculate the amount of stover they might have, how to determine a value for the nutrients in the stover, the cost of corn stover, and so on. A corn stover conversion template comprised of examples (see Appendix A) was developed to assist in understanding some of the calculations typically associated with cornstalk removal. These calculations include harvest costs, estimating the value of the nutrients in stover, and amount of stover removal. It is available on the OFA website under the Bioeconomy tab (https://ofa.on.ca/issues/overview/bioeconomy).

2.2 Markets for Co-products

Throughout this project one risk that was identified is the need to find high value markets for C5 sugar and lignin co-products. Finding higher value markets assists in decreasing the risks associated with the financial model. The biobased products are competing for markets with petroleum based products so the price of oil and the cost to produce the bioproducts are intricately related. The biobased products must be available at a similar price to petroleum based products, with a lower environmental footprint yet they must also have the same or better physical properties such as strength, ability to withstand heat, etc. Over the longer term however, the potential exists for significant opportunities with an estimate of over $375 billion globally in sales of bioproducts by 2020 (McKinsey as reported by BIO, 2016).

A discussion of C5 sugar and lignin co-product markets follows.

C5 Sugar

The model uses the molasses market for livestock feed as the benchmark price for C5 sugar. This means that the C5 sugar is currently priced in a low value market. Two examples of C5 sugars are arabinose and xylose. There is research being undertaken to meet the needs of higher value markets for C5 sugar from biomass (ICFAR, 2016; BIOCORE, 2014a; IEA). Some of this research is in the area of food and beverage production (Zhai, 2014; BIOCORE, 2014a). Being able to obtain a very pure, high quality C5 sugar from biomass could potentially draw high prices however the production process is not yet cost-competitive and is a limiting factor (BIOCORE, 2014a).

Lignin

Although there are several applications for lignin such as fuel, chemicals and materials, there is a lack of high value markets currently (ICFAR, 2016). For lignin co-products $40/tonne is used in the financial model as it is assumed it is used for energy purposes. It is difficult so far to find ways to breakdown lignin into value-added chemicals or other platforms in a cost-effective and efficient manner (Kurian et al, 2013). Various processes such as enzymes, hydrolysis, chemical, mechanical, steam, etc. are being tested (US DOEs, 2016). Processing lignin usually requires a number of steps and the logistics of dealing with significant amounts of biomass can be a major issue (Singh, 2016). In the future it will be possible to have different lines for lignin at a plant but ensuring there will be a market for the end product(s) is crucial (Singh, 2016).

Carbon Black

One option that is currently showing some promise in Ontario is in the area of bio-carbon to replace petroleum based carbon black. Tires represent much of the market for carbon black. Competitive Green Technologies is producing BIOBLAKR® and it is reported to be a substitute for carbon black in the manufacturing of some auto parts (Schaer, 2016). Other potential uses for lignin-based carbon black products include resins, adhesives, packaging materials and composites (ICFAR, 2016). These value-added markets could add greatly to the economic viability of a bioprocessing plant. For example, it is estimated that bio-carbon could be worth $300/ton (M. Tiessen as reported by Schaer, 2016). There are challenges however, that must be overcome with respect to the size of the lignin molecules, the process needed to break down the lignin for each type of end product, the yield and purity of the resulting product(s), and the cost to produce the product (ICFAR, 2016). As stated previously, if a product can't be produced at a price point close to petroleum based carbon black then it's unlikely to be a viable option.

Bio-char

Another option for lignin is with respect to biochar production through pyrolysis (heat). Pelletized biochar from biomass lignin could potentially be used to improve soil health, specifically the soil carbon content (Singh, 2016; McLaughlin, 2016). It appears that research needs to be undertaken though to better understand if and how this could work in Canada with different types and potential combinations of biomass (Singh, 2016; Laufer & Tomlinson, 2013; IBI). However, it is possible that as companies work to better demonstrate the potential benefits of bio-char it could result in substantial market opportunities, for example in production agriculture, within ten years (McLaughlin, 2016).

It appears at this time that each project/business venture must determine the best fit and market with respect to C5 sugar and lignin co-products. This will depend on the technology in use at the plant and may be determined by the end-product market specifications.

3.0 The Financial Model

The 2013 report concluded that the recommended model is a bioprocessing co-op. In the co-op a price for corn stover is estimated based on sugar prices and yields at the sugar plant so that a target return on investment (ROI) of 15% is achieved. The model assumes 250,000 tonnes of stover at 0% moisture yield 115,000 tonnes of cellulosic sugar and 90,000 tonnes of lignin co-product. The financial model that was updated in 2015 included a 2 year ramp up period during which cornstalk inventory would start being accumulated and plant testing and ramp-up would occur prior to full production assumed in the third year. The following assumptions were used: Year 1 – 50% of fixed costs, 25% of variable costs and no revenue; Year 2 – 100% of fixed costs, 75% of variable costs and 50% of revenue. The administration costs were held constant at $C250,000 per year because even though full operations are not attained in Year 1 and Year 2 there will be considerable work involved in communicating with producers, sourcing biomass, logistics, etc. It is assumed that the ROI calculation is over 10 years although full revenue potential is not reached until Year 3.

The financial model shown in Table 2 assumes the base price for sugar to be $C434/tonne which reflects the 5 year average price (2012 through 2016). It should be noted though that the average February 2017 price is approximately $C590/tonne due to an increase in prices that began in mid-2016. World sugar prices and the Canada-US exchange rate can significantly impact the results in the financial model and represent risks to the project. As stated previously, it is important to seek higher value markets for co-products in the C5 sugar stream as well as lignin. Research is ongoing for these co-products but achieving consistent, high purity products will be key in the future and is dependent on the end market targets. For the model the price of co-products remains at $40/tonne.

Table 2 shows that $97.14/tonne at 0% moisture (or $82.08/tonne at 15.5%) on average can be paid for the cornstalks for the first 10 years with the 15% ROI target being achieved. This is actually the price identified in the 2015 report that would cover the harvest costs, nutrient replacement, storage and transportation costs to deliver the cornstalks to a plant. The calculations take into account the two year ramp-up period as discussed previously where accumulation of cornstalk inventory begins and plant testing occurs.

Table 2 Financial Model for Bioprocessing Co-operative

	Value
Price of cellulosic sugar ($C/tonne)	**$434.00**
Price of co-products ($/tonne)	$40.00
Cost of cornstalks ($/tonne) at 0%	$97.14
Cost of cornstalks ($/tonne) at 15.5%	$82.08
Production and Revenue	**Value**
Cellulosic sugar revenue ($ million/year)	$42.42
Co-product revenue ($ million/year)	$3.06
Total revenue ($ million/year)	$45.48
Cost Items	**Value**
Operating costs	
Cornstalks cost ($ million/year)	$21.86
Operating costs ($ million/year)	$9.75
Financing costs	
Interest ($ million/year)	$1.47
Loan repayment ($ million/year)	$5.88
Sub-total financing costs ($ million/year)	$7.35
Net income ($ million/year)	$6.53
Return on investment (%)	15.0%

Note: Costs related to pre-processing activities, if needed, have not been included.

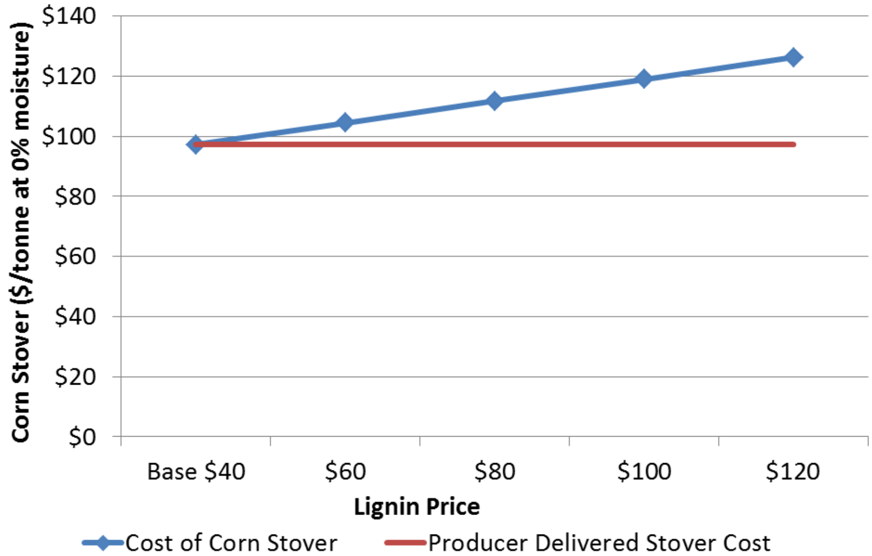
3.1 Sensitivity Analysis Related to Co-Products Values

As stated previously, to reduce the risk for this type of project it is important to seek high value markets for co-products. For example, lignin co-products have been priced at $40/tonne in the 2015 report and as the base price in this example. It is assumed that lignin would be burnt as an energy source until higher value markets become available.

Figure 2 shows potential prices that could be paid for cornstalks depending on the price of lignin, using the 5 year average price for sugar of $434/tonne and a 15% ROI. For example, if the lignin co-products could be sold at $100/tonne then the price that could be paid for corn stover is $119/tonne at 0% moisture, considerably higher than the $97.12/tonne possible at the base lignin price of $40/tonne.

Competitive Green Technologies of Leamington has recently had some success in the higher value markets so values greater than $100/tonne could be possible for lignin in the future however at this time these markets are limited. They need to be identified and defined in the planning stage of a venture.

Figure 2 Effect of Lignin Price on Cost of Cornstalks



Note: It is assumed that a sugar price of $434/tonne is used.

3.2 Sugar Value in Cornstalks

The 2015 report discussed that another way to determine the sugar price used in the financial model is to identify the potential value of the cellulosic sugar when cornstalks are processed. This would then be input into the model to determine the price that a plant could pay for cornstalks in the bioprocessing co-op model.

Using the assumptions from the 2015 report, corn stover has the sugar yield and value per tonne as shown in Table 3 using the ICE Contract 11 nearby sugar futures on March 23, 2017. For the C5 sugar it is still assumed that the Louisiana molasses price is used. The Canada-US exchange rate on March 23 was used to convert the prices into Canadian dollars. Table 3 indicates that the sugar value in one tonne of stover was estimated to be $C160.91 at 15.5% moisture or $C190.42 at 0%.

Table 3 Cornstalks Sugar Yield and Value

Variable	Yield/tonne (15.5% moisture)	Value/tonne (15.5% moisture)
C6 sugar	0.250	$129.42
C5 sugar	0.149	$31.48
Total sugar	**0.399**	**$160.91**

*Based on March 23, 2017 sugar price and exchange rate

The bioprocessing co-op model discussed previously assumed that 115,000 tonnes of sugar would be produced from 250,000 tonnes of cornstalks. The estimated value for C5 and C6 sugars produced is $190.42/tonne of stover at 0% moisture. If this value can be obtained from 250,000 tonnes of dry stover delivered to the plant resulting in 115,000 tonnes of sugar then the average sugar price is $C414/tonne on the 115,000 tonnes of sugar produced. This value is then input as the price of sugar in the bioprocessing co-op model. Taking into account the ramp-up phase the maximum amount that can be paid for cornstalks is $C87.81/tonne ($C74.20/tonne at 15.5% moisture). This is considerably higher than what was calculated in 2015 when the value of sugar in the stover was $C295 resulting in $C31.83/tonne at 0% ($C26.90/tonne at 15.5% moisture) that could be paid for cornstalks based on the current sugar value in the stover. This emphasizes the impact that the price of sugar has in this model.

3.3 Project Risks

This project has made significant progress however it still carries some risks and there are a few key areas that would benefit from time and research. These are outlined below.

i) Weather – Weather at time of planting through cornstalk harvest can affect the number of corn acres planted, the yield and the conditions at harvest. A plant such as that envisioned in this project requires a large amount of cornstalks ideally harvested under dry conditions. Having a technology that is flexible and capable of handling other feedstocks (i.e. wheat straw) is a way to mitigate weather risk.

ii) Sugar price – The world sugar price has been used in the financial model. It has fluctuated significantly during the last ten years and affects the price that can be paid for the cornstalks.

iii) Exchange rate – The exchange rate affects the price of equipment such as that used for harvesting cornstalks that are priced in US dollars.

iv) Markets – The model used for this project relies on variable world sugar prices and low-value co-product markets. There is potential that high value markets will become available over time for bioproducts and these markets need to be sought out. Having off-take agreements prior to plant commissioning helps to further de-risk the project.

v) Technology – Several technologies are being researched globally but any technology must be well tested before it is ready to be used at plant scale.

4.0 Conclusions

There is potential for a cornstalk to bioprocessing facility in southwestern Ontario. Sufficient volumes of cornstalks are available as corn yields continue to increase over time. A bioprocessing co-op was determined to be the best model so that producers can be part of the value chain and a cellulosic sugar plant would be assured of supply at less variable cost.

Concern regarding the sustainability of cornstalk removal from fields is still a priority but research is ongoing to provide assurances to producers, the government and the public that it is possible. Satellite imaging is providing the opportunity to estimate corn grain and, therefore, corn stover yields prior to harvest. High yielding fields can be identified to assist in timely and efficient stover harvest. As well, research into the effect of different stover removal rates on corn yield is being compared on different types of soils and with different tillage practices. These types of research projects will provide a better understanding of corn stover harvest under Ontario conditions and how it can be done sustainably.

The price of sugar, exchange rates and market revenue are risks for the financial model. The model was based on the world sugar price which is highly variable. Higher value markets for C5 sugar streams and lignin co-products need to be identified to reduce risk for this model. At the present time research is ongoing globally in these areas and there is considerable potential but cost-competitive, efficient technologies resulting in high purity products are not readily available. In the future these streams will need to be recognized early on in the planning of a venture so processes can be incorporated such that the specific targets can be achieved.

Momentum is building to move towards a more biobased economy in order to improve upon current products and to meet government policy intentions with respect to GHG reduction targets. Corn producers may benefit by moving up the value chain and participating in cellulosic sugar production for use in biobased products.

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Appendix A

Corn Stover Conversion Template

Appendix A Corn Stover Conversion Template

You may input data in cells highlighted in yellow.

Example 1	**A Typical Supply Chain Budget for Corn Stover**		Converted to	
	Reported moisture content of stover	15.0%	15.5%	moisture
	Harvest Costs	**$/ton**	**$/tonne**	
	Stalk chopping	$8.00	$8.77	
	Rake	3.00	3.29	
	Baling	13.00	14.25	
	Transportation to field edge	2.00	2.19	
	Storage	8.00	8.77	
	Nutrient replacement	12.00	13.15	
	Other	0.00	0	
	Corn Stover Cost – farm gate	**$46.00**	**$50.41**	
	Other	0.00	0	
	Transportation	19.00	20.82	
	Corn Stover Cost - delivered	**$65.00**	**$71.23**	

Example 2	Estimating Value of Nutrients in Stover	
	Grain corn yield (bu/ac at 15.5% moisture)	180
	% stover removal	30%
	Stover removal (tonnes/acre)	1.37
	Input price of correspondong fertilizers in yellow areas.	

Nutrient	Analysis[1]	Potential Availability for Next Year Crop (%)[2]	Product	$/tonne	**Value ($/tonne at 15.5% moisture)**	
estimated N removed	0.87%	25.0%	Urea (46-0-0)	$624.09	$2.49	
estimated P removed	0.09%	40.0%	MAP (11-52-0)	$811.72	$0.91	
estimated K removed	0.90%	90.0%	Potash (0-0-60)	$611.82	$8.38	
Total NPK removed					**$11.78**	per tonne at 15.5% moisture
					$16.16	per acre at 15.5% moisture

[1] Based on fall Ontario corn stover sampling and analysis.
[2] Based on NMAN and industry sources.

Example 3	Price of Stover vs Value of Nutrients Removed		
	Price of stover $/tonne at 15.5% moisture	$15.00	
	Nutrient removal $/tonne (from Example 2)	$11.78	
	Difference: Stover price - value of nutrients removed	$3.22	per tonne

Example 4	Costs of Stover Management	Some field activities might be reduced or eliminated if a portion of corn stover is removed.		
	Stalk chopping[3] ($/acre)	$16.00		[3] Source: OMAFRA Survey of Custom Farmwork Rates Charged in 2015, Area 1 average
	Chisel plow/soil saver[3] ($/acre)	$26.00		
	Disc[3] ($/acre)	$19.00		
		Some research suggests a potential increase in yield when corn follows corn and some stover is removed.		
	Potential yield increase of next (corn) crop[4]	5.0	bu/acre	[4] DuPont Pioneer shows 5.1 bu/ac advantage while ISU and USDA report a 0% to 5% increase
	Price of corn ($/bu)	$4.40		
	Potential increased income ($/acre)	$22.00		

Example 5	$/bale	$9.00			
	# bales/acre	3.00			
	weight/bale (in pounds)	1,200			
	Stover removal/acre	1.63	tonnes/acre		
	$/tonne of stover	$16.53	or	$27.00	per acre

Example 6	Convert $/ton to $/tonne	
	$/ton of stover	$15.00
	$/tonne of stover	$16.53

Example 7	bale weight (in pounds)	1200	=	0.54	tonnes/bale
	bale moisture	15%			
	bales/ac	3			
	tonnes/acre (at 0% moisture)	1.39	or	1.64	tonnes/acre at 15.5% moisture
	# of 1200 lb bales/ac (at 0% moisture)	2.6			

Example 8	corn yield (bu/acre) at 15.5% moisture	180			
	stover removal rate	30%	=	1.37	tonnes/acre at 15.5% moisture
	average bale weight (in pounds, 0% moisture)	1200			
	bales/acre	2.13			

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