Development of a Business Case for a Cornstalks to Bioprocessing Venture

FINAL REPORT

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RIDGETOWN CAMPUS

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Executive Summary

The objective of this report is to investigate the potential for a commercial scale biorefinery that converts 250,000 dry tonnes of corn stover annually to cellulosic sugar. This includes examining various potential pricing options and business models that could be used for this bioprocessing venture. The potential location for the sugar plant is Sarnia, Ontario due to the large chemical industry located there. As a result, the potential volume, availability and sourcing of corn stover discussed in this report is focused on the four county region of Lambton, Huron, Middlesex and Chatham-Kent in Southwestern Ontario.

Corn stover has traditionally been used for livestock bedding and cattle feed. The harvesting of corn stover on a large scale is relatively new for Ontario. With this comes some uncertainty and risks but also potential.

There are five key items covered in this report. They include pricing options, business model options, discussion of the recommended business model, financial scenarios and sensitivity analysis, and risk identification and mitigation. A spreadsheet template was developed to run the sensitivity analysis by changing various parameters and will be applicable to other projects.

Potential options for pricing stover include the following:

- based on harvest, nutrient removal, and storage costs
- based on feed replacement value
- based on wheat straw value
- based on further processed bioproducts value

Using these options, the price of stover in 2012 would vary from $98/dry tonne at the farm gate based only on harvest, nutrient removal and storage costs; to $159/tonne based on a feed replacement value; and to $149/tonne based on wheat straw value. The price of sugar on the world market is highly variable; therefore, the price for sugar (i.e. corn glucose) from other sources provides a ceiling for stover values based on sugar yield. This study attempts to establish a relative base price for corn stover. However, individual producer costs will vary significantly due to grain corn yield and hence biomass yields, equipment used, and transportation distance to the sugar plant.

Potential options for business models include:

- direct sale
- request for purchase
- supply co-op
- bioprocessing co-op

The recommended business model is a bioprocessing co-op. The financial analysis in this report has used conservative assumptions and a target of 15% return on investment (ROI) after tax based on private investment funding. The base scenario assumes 250,000 tonnes of stover yields 115,000 tonnes of cellulosic sugar and 90,000 tonnes of lignin coproduct. The price a stover producer receives depends on several factors such as sugar prices and sugar yields. Based on the sensitivity analysis, the price that a stover producer might receive could potentially range from $37 to $184/dry tonne. These are estimated values for the current time, but several opportunities exist to reduce the corn stover cost in high cost scenarios based on the sensitivity analysis.

The price received for the stover would be directly related to the financial performance of the cellulosic sugar producer and possible dividend payments. By participating in a bioprocessing co-op, corn stover producers can share in the returns of the sugar plant and potentially increase the value received for their corn stover. Feedstock supply accounts for the highest proportion of annual operating costs in the bioprocessing co-op model. Annual feedstock supply and operating costs are roughly 50% to 60% of the total initial capital costs for the sugar plant.

Potential opportunities to increase efficiency, reduce corn stover procurement costs, and increase return on investment include:

- the use of new harvesting equipment and logistic processes (eg. high density balers, two pass harvest systems)
- the use of field advisors to ensure sustainable stover harvest on a site specific, field by field basis
- recent Ontario grain corn yield data suggests there are large acreages within the four county region with yields well above 150 bushels/acre where it may be beneficial to remove some of the stover
- incorporating a process to remove the nitrogen (N), phosphorus (P) and potassium (K) from the stover and resell it as a liquid fertilizer to provide additional revenue stream for the value chain co-op
- decreased operating costs and capital costs as current sugar conversion technology improves and new technology emerges

The ability to source sufficient quantities of stover each year on an on-going basis at a cost that is economical for both the sugar producer and corn stover producer is a critical factor to the success of a biorefinery. The sugar plant will need to be feedstock neutral, so alternative biomass sources could be used to ensure year round supply.

Next steps for a potential cornstalks to biochemical venture include:

- selecting a technology to convert biomass to sugar
- development of a harvest calendar with alternative feedstocks
- research into supply system efficiency
- research into business innovation to support a biorefinery
- construction of a demonstration size plant to test the sugar conversion technology
- educating the public and producers about all stages of the project.

A demonstration plant could help address some of these issues and build producer and community interest.

Great potential exists for a sustainable cornstalks to bioprocessing venture in Southwestern Ontario. At the farm level corn producers could benefit by moving up the value chain and addressing some agronomic issues by removing excess stover. The utilization of cellulosic sugar produced from corn stover to produce green chemicals would reduce the environmental footprint through lower greenhouse gas emissions and increased carbon credits in concert with worldwide efforts to develop green chemicals.

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Introduction

1.0 - Introduction

This report focuses on the development of a business case for cornstalks to biochemical processing. The main objectives of this project are to examine various potential pricing options and business models that could be used for a bioprocessing venture that converts 250,000 dry tonnes of corn stover annually into cellulosic sugar. Cellulosic sugar can be used to produce many biochemicals including biosuccinic acid.

Figure 1 shows the compositional breakdown of three types of biomass: wheat straw, corn stover and switchgrass. The three are very similar in composition in terms of cellulose and hemicellulose. Cellulose and hemicellulose can be hydrolyzed to sugars and then used in a variety of processes including the production of biochemicals. Lignin cannot be converted to sugars but can be used in other applications such as being burned as a fuel source.

Figure 2 shows schematically the various steps involved in the corn stalks to bioprocessing process and the potential involvement for various

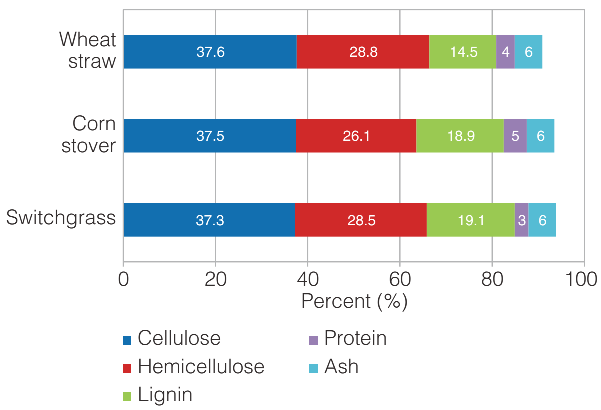


Figure 1. Compositional Breakdown of Three Types of Biomass

Source: Lee, et al. 2007.

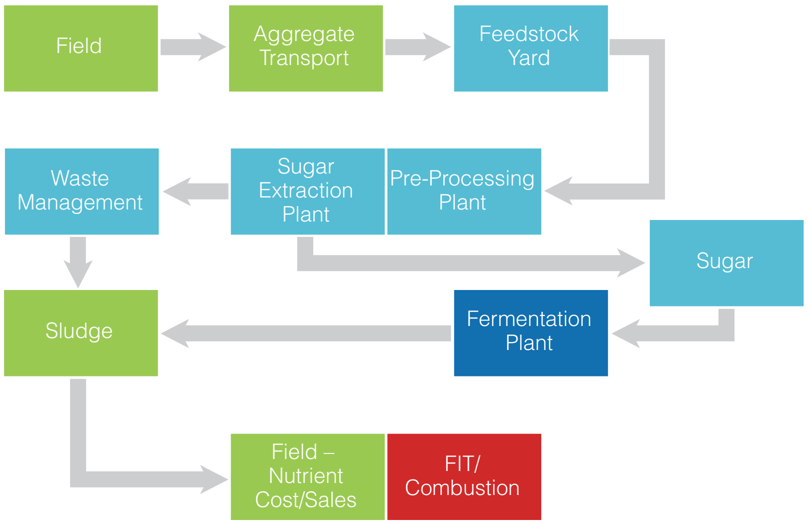


Figure 2. Potential Value Chain Diagram

Source: Industry sources.

value chain stakeholders. The green boxes denote corn stover producer or farm-level activities while the blue boxes indicate where there could be equity participation from various stakeholders. The corn stover producers would be required to harvest the stover themselves or have it custom harvested. Aggregators would assemble the bales and arrange for transportation to the feedstock yard. The sugar plant would have a yard capable of holding perhaps 3 to 7 days of corn stover bales to ensure constant supply. Cellulosic sugar would be sold to further value-added customers and management of the coproduct streams (i.e. lignin) could potentially be additional revenue sources for the sugar plant.

There are many factors to be considered when developing a business case for this type of project. Some of these include the following: sustainable corn stover removal; producer participation; pricing options; business model options; identifying potential risks and ways to mitigate these risks. This report will begin with background information based on a review of literature about corn stover removal and pricing methods followed by an assessment of Ontario corn stover potential, possible pricing options and business models, further research areas and finally, conclusions and next steps. The terms stover, residue and biomass refer to corn stover unless indicated otherwise and the term dry tonne refers to biomass that is 100 per cent dry.

2.0 – Corn Stover Removal – Background Information

This section provides information on corn stover removal from various sources of literature.

2.1 Pros and Cons for Corn Stover Removal

Increasing corn yields, particularly over the last decade, have increased the amount of stover remaining after the grain is harvested. For each bushel of grain corn yield of 56 pounds, an approximately equivalent amount of corn stover is produced (Glassner et al., 1999; Petrolia, 2008; Morey et al., 2010). Removing some of the excess stover could be beneficial by potentially increasing yields and by potentially providing additional income for producers. Corn stover is slow to decompose in relation to some other crops such as soybeans (Glassner et al.). The increased amount of corn stover left on the ground causes concerns because it can affect seed placement the following year, cause wear and tear on equipment, delay planting because it takes longer for the soil to dry and warm, etc. (Al-Kaisi and Hanna, 2008; Glassner et al.; Oo and Lalonde, 2012).

However, there are also issues associated with stover removal that need to be addressed. One concern is with respect to compensation for nutrients that are removed when the stover is harvested (Stewart, 2011; Woortman et al., 2012; Hess et al., 2009; Brechbill and Tyner, 2008). Other concerns focus on the long-term effects on future crops in terms of potential erosion related to the amount of stover removed (Woortman et al.; Stewart), compaction, level of soil organic matter (Woortman et al.; Stewart; Oo and Lalonde) level of carbon in the soil (Archer, 2009; Oo and Lalonde) and yields. In Ontario it is estimated that approximately 4 tonnes/acre of residues are needed each year to maintain soil organic matter (Stewart; Oo and Lalonde).

2.1.1 Agricultural Producer Participation

If agricultural producers are going to consider harvesting corn stover, there are numerous factors to take into account including how the stover is priced, how much will be removed, who will be responsible for baling, storing and transporting the stover, when does ownership of the stover change hands and so on. Addressing these issues will assist greatly in securing producer participation and support of stover harvesting.

Several surveys have been undertaken in the U.S. to determine producers' level of knowledge about selling biomass and their potential interest in selling biomass. Tyndall (2007) found that nearly 70% of survey participants were unknowledgeable about corn stover and its potential markets. In fact, all of the survey results reviewed found that there were at least some producer concerns about harvesting corn stover and other types of biomass (i.e. corn cobs, purpose grown crops). These concerns included weather and the timing of harvest (Jarboe, 2012), the potential for soil erosion and loss of nutrients or the need to replace nutrients (Jarboe; Marketing Horizons, Inc., 2001; Tyndall; Hoque, 2013), markets for biomass and the pricing of biomass (Jarboe; Hoque) and the capital investment needed for harvesting equipment (Tyndall).

With respect to potentially selling stover, Tyndall found that 46% of Iowa farmers surveyed were uninterested in selling while 17% showed interest and 37% were neutral on the question. This is not surprising as the new chemistry economy is just emerging. Informing survey participants about potential uses for corn stover or other biomass, however, seemed to increase the level of interest in selling biomass. For example, when survey participants were told of potential uses for biomass (e.g. biorefineries), 74% indicated they would consider selling stover if there was enough money to justify doing so (Marketing Horizons, Inc.). Jarboe reported that 33% of those surveyed showed an interest in possibly selling biomass for biofuel production. Another positive response was reported in the Iowa Farm and Rural Life Poll (2006). Respondents in that survey were asked if they would “sell crop residues if it were possible to manufacture biofuels out of those materials” (p. 3) and 50% indicated that they agreed with the statement.

It is recognized, however, that there are producers who will be unwilling to sell their corn stover. The concerns identified above will impact producer willingness to participate in harvesting stover. However, a participation rate of 50% is commonly used in research and economic modelling of biomass harvesting (Hess et al., 2009; Perlack and Turhollow, 2002; Petrolia).

The material discussed in this section relies heavily on information from Iowa. Iowa is the number one corn producing state (USDA, NASS) and there are 41 corn grain ethanol plants located within the state (Iowa Corn Growers Association). Although Iowa may be perceived as being receptive to innovative corn projects (i.e. ethanol production), the survey results previously cited indicate that while Iowa producers see potential opportunities for harvesting corn stover, they also have some concerns. Some producers may see value in supplying stover or other biomass as a means to support a bio industry, but most farmers will ultimately need a financial incentive and extension support to do so (Milhollin et al., 2011; Thompson and Tyner, 2011; Morey et al.; Perlack and Turhollow).

From December 2012 through February 2013 a total of five focus meetings were held with Southwestern Ontario corn producers in the four county region of Lambton, Huron, Middlesex and Chatham-Kent (Bryan Boyle & Associates). The producers grow sizeable acreages of corn annually ranging from 800 acres to more than 5,000 and some have experience baling or transporting corn stover. There were 65 participants in the focus meetings and after hearing about the concept of a cornstalks to biochemical project, their initial reactions were mixed. Some potential advantages identified related to agronomic, financial and environmental factors. Pricing was the primary concern identified by focus meeting participants, but other potential disadvantages focused on compensation for nutrient removal, compaction, weather issues affecting stover harvest and removal, logistics, quality standards, and infrastructure.

In order to move a cornstalks to biochemical project forward, the focus meeting participants identified key focus areas including the following:

1. financial sustainability for the corn grower and processor, price discovery, profit sharing;
2. on-farm trials and research at the processor and end user levels;
3. establishment of standards and protocols with respect to harvest, storage, delivery and payment;
4. availability of resources such as capital, corn stalks, equipment, infrastructure;
5. organizational development and the approach, co-op or corporate model; and

6. education and promotion to stakeholders of the approach to the project targeting growers, processors, end users and other stakeholders.

Overall, once the meetings were completed, 65% of the focus meeting participants indicated interest in the project and the possibility of sourcing, harvesting or transporting stover while only 9% were uninterested for a variety of reasons.

2.1.2 What is "Sustainable" Removal?

An important consideration for agricultural producers participation will be that biomass harvest is implemented in an environmentally sustainable way and that soil health is not affected detrimentally. This means that a minimum amount of residues must be left to protect the soil and maintain soil characteristics (i.e. tilth, organic matter, carbon, etc.). The amount of biomass removed in a sustainable system is site-specific and depends on factors such as crop rotation, slope of the land, management practices, use of manure, use of cover crops, etc. (Kludze et al., 2010; Oo and Lalonde). Weather also plays a role in the amount of biomass produced (Li et al., 2012). Some ways to potentially increase the amount of stover that could be sustainably removed include increasing crop yields, growing cover crops, using conservation tillage, and adding manure.

The literature suggests various stover removal rates. Morey et al. assumed that 70% of corn stover was removed every other year resulting in an average of 35% removed per year. They believed this would result in less compaction than harvesting every year and would be more efficient. Thompson and Tyner assumed 33% stover removal or 1.4 dry tonnes/acre. Perlack and Turhollow also assumed a 33% removal rate but Hess et al. used 38%. Blanco-Canqui and Lal (2009), however, found that only up to 25% of corn stover could be removed.

POET's Project LIBERTY producer handbook indicates harvest rates of 25% or less, or 0.9 to 1.4 dry tonnes/acre (POET-DSM Advanced Biofuels, 2012). DuPont goes a step further by not harvesting stover unless the average corn yield is 180 bushels/acre, the slope of the field is 4% or less and they are removing 1.8 tonnes/acre (Dickrell, 2012). Some of the literature did not stipulate a minimum amount of grain corn yield before stover harvest is permitted. Wilhelm et al. (1999) and Wortmann et al. report that stover should not be removed on fields that yield less than about 150 bushels/acre in grain while Gan et al. (2012) report that in some situations stover should not be removed at all.

There are concerns about corn stover harvesting and the potential negative impacts on soil organic matter (SOM), soil erosion and soil fertility (Archer, 2009; Osborne et al., 2012). Rankin (undated) quantified the potential impact on soil at an estimated $0.33/tonne of stover depending on how often stover is removed and how much is removed. However, research by Karlen & Birrell (undated) conducted over three years, indicated that no significant effects resulted from corn stover harvest when 1.4-1.8 tonnes/acre of stover was removed.

With respect to impacts on future crops, it is difficult to assess a value because the effects will be very site specific (Milhollin et al., 2011). Some argue that crop yields could actually increase if excess stover is removed because soil that warms faster in the spring allows earlier seed germination (POET). In Nebraska it was reported that corn yields decreased by 2.2 bushels/acre for each tonne of stover removed when soil moisture was low (Wortmann et al., 2012). Participants at the five Ontario focus meetings held during the winter of 2013 for this project expressed concern about future yields if compaction occurred during stover harvest in wet harvest years such as 2012.

The potential effects on soil organic carbon (SOC) may be more important than erosion when deciding how much stover to harvest (Sesmero, 2011; Wilhelm, 2007). In fact, Wilhelm reported that more stover was required to maintain SOC than was needed to control erosion. Milhollin et al. indicate that at removal rates greater than 25%, SOC is reduced.

A model presented by Anand et al. (2010) shows the possibility of determining a sustainably harvestable corn stover removal rate that takes soil organic carbon into account. The model incorporates factors such as tillage practices, percentage of residue harvested, nitrogen replacement, etc. This could make the potential amount of stover removed very site specific.

There is debate about what tillage practice should be used when stover is being harvested. Glassner et al. report that tillage decreases organic matter and negatively affects fertility levels. Wortmann et al. and Wilhelm et al. report that no-tilling allows greater amounts of stover to be removed. Nafziger (undated) found that using tillage in continuous corn did not affect future yields, but in no-till most of the residue had to be removed to maintain yields. Also, some believe that conservation tillage may be acceptable in certain situations such as when crop yields are excessive (Archer) or when cover crops are incorporated into the cropping mix (McDonald, 2010). In the U.S. Billion-Ton Update reports (2011) residue removal was only allowed on reduced-till and no-till acres.

As stated previously, the use of cover crops may be helpful in terms of controlling erosion (Woortman, et al.; Hoorman, 2009), particularly when tillage is undertaken, but cover crops will not replace the nutrients that are removed (Wortmann et al.) when corn stover is harvested. It is important to note, however, that in processing tomatoes the use of cover crops resulted in similar or better yields compared to not using a cover crop (Van Eerd et al., 2011). In Ontario there is interest in cover crops particularly with respect to benefits surrounding nutrient availability for subsequent crops (Verhallen et al., 2001; Kladivko, 2011; Hoorman, 2009).

2.2 Availability of Corn Stover in Ontario

The production of grain corn and stover are closely related and are often assumed to be at a ratio of 1:1 (Glassner et al.; Petrolia; Morey et al.). Therefore, it is important to analyze corn yields over time. Figure 3 shows average grain corn yields per year for Ontario and Iowa from 1960 to 2012. Iowa is used for comparison purposes because it is the largest corn producing state in the U.S. and they have experience harvesting corn stover. POET and DuPont are building cellulosic ethanol plants in Iowa that will use corn stover. Ontario can benefit from lessons learned

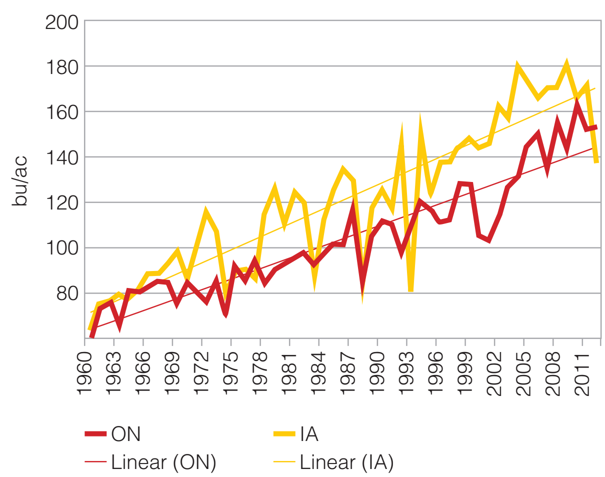


Figure 3. Ontario and Iowa Average Annual Corn Yields (bu/ac)

Source: Statistics Canada, USDA

in the U.S. with respect to corn stover harvest, but it is important to recognize differences in growing conditions (climate) and crop productivity between Iowa and Ontario. In both regions, corn yields have risen significantly over time and this trend is expected to continue as a result of new corn varieties introduced in recent years. Between 1960 and 2012 there were only 7 years when Ontario's average yield was higher than Iowa's. Extremely dry conditions in Iowa in 2012 resulted in a yield of 137 bushels/acre versus 153 for Ontario.

Figure 3 shows that the long term yield trend is up for both Ontario and Iowa, but Iowa is trending higher at a faster rate (approximately 2.1 bushels/acre/year yield increase since 1960 for Iowa versus 1.8 bushels/acre/year for Ontario). This trend is also illustrated in Table 1 which shows the 10 year averages for Ontario and Iowa since the 1960's. During the 1960's Iowa's average yield was about 6 bushels/acre higher than Ontario, but by the 2000's Iowa was nearly 35 bushels/acre higher. There is only a 1.6 bushel/acre difference for the 3 year time period of 2010 to 2012 largely due to very low yields in Iowa in 2012.

Information from Figure 3 and Table 1 shows that grain corn yields in Iowa are usually higher than yields in Ontario. This is important because much of the literature cited in this document is from

Table 1. 10 Year Average Corn Yield, Ontario vs Iowa (bu/ac)

Period	ON	IA	Difference IA vs ON
1960's	76.2	82.5	6.3
1970's	84.4	100.0	15.6
1980's	98.4	114.7	16.3
1990's	114.7	131.5	16.8
2000's	130.8	165.4	34.6
2010-2012	156.4	158.0	1.6

Iowa and the higher yields in Iowa allow more stover to be removed per acre than can be removed in Ontario. This results in better efficiencies and lower costs than what may be possible in Ontario.

2.2.1 Stover Potentially Available in Southwestern Ontario

The four county region of Lambton, Huron, Middlesex and Chatham-Kent in Southwestern Ontario is the focus for this study. The intention is to keep the distance of the corn stover within approximately 75 km of Sarnia, Ontario where a cellulosic sugar plant would be potentially located.

The four county region is a highly productive agricultural region in Ontario. Class 1 to 3 soils, the best for growing crops in terms of drainage and moisture holding capacity, are found in much of the area and contribute greatly to this productivity along with a long growing season (AAFC, 2013; OMAFRA, 2009).

Tillage practices across the region vary. Census of Agriculture data shows that there has been little change from 2006 to 2011 in the percentage of acres that are no-tilled. In the 2011 Census producers reported that 33% of the acres were no-tilled or zero-tilled, 30% of acres had some tillage but most crop residue was kept on the surface, and 37% of the acres had tillage that incorporated most of the residue. There has been only a modest increase in no-till farming from 2006 when 31% of acres were no-tilled (Statistics Canada).

A common crop rotation in Southwestern Ontario is a 3 year rotation of corn, soybeans and wheat. On some farms forage crops may also be included in their rotation. Figure 4 shows a breakdown of total corn, soybean and wheat acres harvested from 2003 to 2012 for the four counties. The average total acreage for the three crops was 1.7 million acres of which corn acres averaged 550,000. During this time frame corn acres represented 32% of the total acreage while soybean acres were 47% and wheat 21%. The amount of each crop harvested varies each year and is related to many factors such as weather from time of planting through to harvest, relative market prices for the crops, individual farm crop rotation, etc.

Figure 5 shows average county corn yields from 2003 to 2012. It is clear from the data shown that there is considerable variability in corn yields that exists between counties and by year. Across all data points the minimum yield was 127 bushels/acre, the maximum was 181.8 and the average was 154.8 bushels/acre. The 5 year average from 2008 to 2012 was 163.4 bushels/acre. The average yields in 2012 ranged from 162.3 in Huron to 181.8 bushels/acre in Chatham-Kent.

Oo and Lalonde indicated that there is approximately 3.1 million tonnes (at 15% moisture content) of crop residues in Ontario that could be sustainably harvested each year with just over 2 million tonnes located in the southern and western Ontario regions combined. Their work stressed the need to monitor stover removal rates and soil characteristics not just at the county level, but at the farm level as well.

Based on Oo and Lalonde's work within the four county area of Lambton, Huron, Middlesex and Chatham-Kent, the average sustainable corn stover harvest rate ranges from 1.11 tonnes/acre in Chatham-Kent to 1.24 tonnes/acre in Huron at 15% moisture. On a 100% dry matter basis this equates to 0.94 to 1.05 tonnes/acre. These values are based on the assumptions that conservation tillage is used and that corn is grown in a rotation with soybeans and wheat which is a typical rotation for many farms in this region. From 2003 to 2012 the average amount of corn stover that could be harvested sustainably in this region is 546,000 tonnes/year at 100% dry matter. This is skewed by the very high amounts in 2007 and 2012 as shown in Figure 6. The average without these two years is approximately

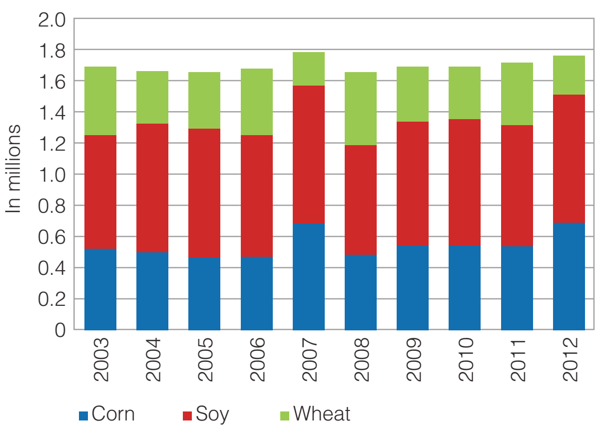


Figure 4. Corn, Soybean and Wheat Acres Harvested in 4-County Region

Source: OMAFRA; Census of Agriculture 2011; Statistics Canada; Agricorp

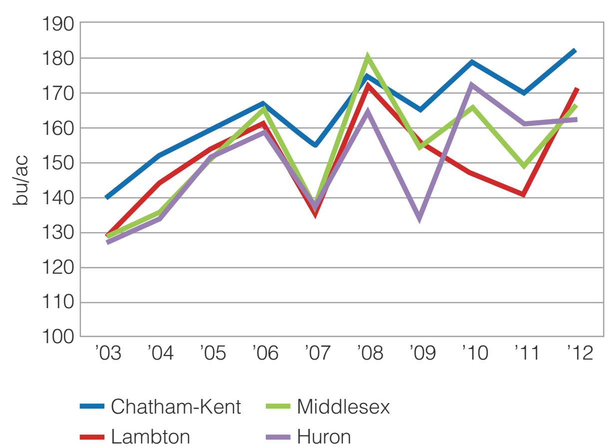


Figure 5. Average Annual Corn Yields by County Source (bu/ac)

Source: OMAFRA; Statistics Canada: Field Crop Reporting Series; Census of Agriculture 2011; Agricorp

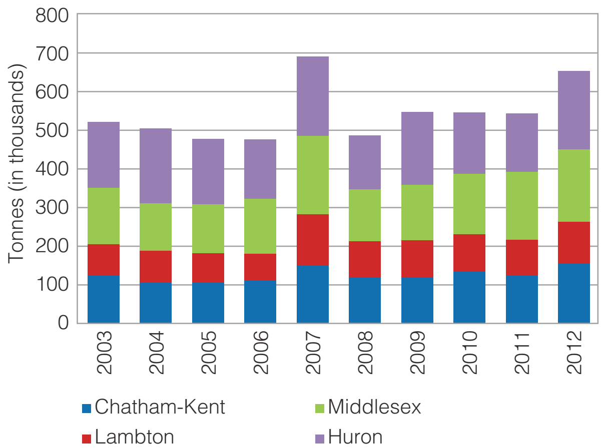


Figure 6. Amount of Sustainably Harvestable Corn Stover (dry tonnes)

Source: OMAFRA; Census of Agriculture; Statistics Canada; Oo and Lalonde

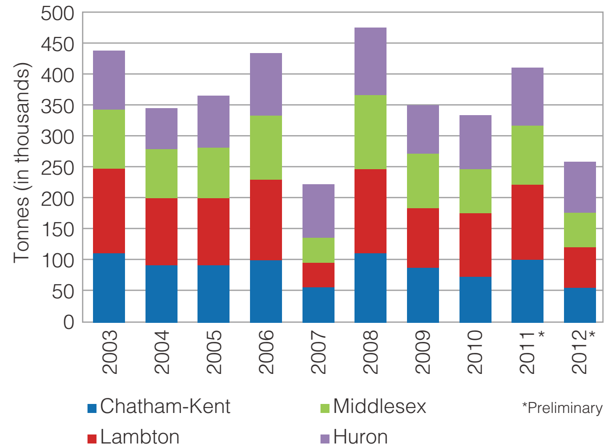


Figure 7. Amount of Sustainably Harvestable Wheat Straw in the Four-County Region (dry tonnes)

Source: OMAFRA, Census of Agriculture, Statistics Canada; Oo and Lalonde

515,000 tonnes. It is important to remember that Figure 6 shows corn stover production based on an average removal rate of 0.94 to 1.05 dry tonnes/acre.

Figure 5 previously showed how much corn yield varies from year to year. In Table 2 data obtained from Agricorp for the four county region illustrates corn acreage broken down into 10 bushel yield increments starting at 150 bushels/acre. The data shows that in 5 of the 6 years depicted in Table 2, more than 60% of the corn acreage in the 4 county region yielded greater than 150 bushels/acre. It is important to highlight the high yielding acres because they have the potential for higher stover removal rates, but the rates should still be site-specific in order to be sustainable. In 2012, preliminary estimates indicate that 313,859 acres yielded more than 180 bushels/acre of corn. While 2007 and 2012 are very similar in terms of total corn acres, the yield breakdowns clearly show that the distribution of acres by yield category can vary significantly.

Wheat straw is another biomass that is available in Southwestern Ontario in large amounts. The amount of wheat straw that could be sustainably

Table 2. Corn Acres by Average Yield Category for Four County Region

Bu/ac	2007	2008	2009	2010	2011	2012p
4-county corn acres*	689,800	489,000	545,100	547,000	542,230	688,717
150-159 bu/ac	71,529	33,319	77,117	49,679	43,005	35,482
160-169	54,930	49,907	69,798	59,778	72,408	65,465
170-179	31,132	52,800	62,150	89,251	96,445	64,416
>= 180	43,045	250,530	127,353	206,396	222,728	313,859
% of 4-county corn acres that are >=150	29%	79%	62%	74%	80%	70%

Source: Agricorp. Data is representative of the acres that premiums are paid on. P = preliminary. *OMAF, Statistics Canada: Field Crop Reporting Series harvested in the four county region is shown in Figure 7. This is based on the wheat acres harvested annually and a removal rate of 1.2 tonnes/acre (at 15% moisture) as documented by Oo and Lalonde. The four county total ranges from 222,000 tonnes in 2007 to 474,000 tonnes in 2008 at 100% dry matter but the average during this time period is 363,000 tonnes.

Although Ontario farmers grow significant acreages of soybeans (i.e. 2.58 million acres harvested in 2012), the harvest of soybean residue has not been included in this discussion. Based on work by Oo and Lalonde, the U.S. Department of Energy's Billion-Ton Update and other sources, it is believed that it is not possible to remove soybean residue without losing soil organic matter. Furthermore the harvesting activity may not be feasible from an economic perspective.

2.2.2 Current Residue Removal

Ontario farmers were asked in the 2011 Census of Agriculture to indicate the amount of land from which crop residue was baled. This included straw and corn stalks but did not include hay, corn silage or other forages. There were 13,742 farms in Ontario that reported baling crop residue from 873,120 acres (Statistics Canada). No further breakdowns were provided but it is expected that much of this was for straw rather than stover. To put this in perspective, Census data showed that in Ontario 1.5 million acres were planted to cereal grains (i.e. wheat, oats, barley, mixed grain), 2 million to grain corn, and 2.5 million acres to soybeans, so the baled crop residue came from approximately 15% of these crop acres.

Baling stover is different than baling straw in one critical area – time of year it occurs. With straw, there are potentially several months when baling can take place and the moisture content is not often a problem. However, corn stover is often harvested in the fall when weather can be unpredictable and there is a rush to complete it before winter. Lower moisture levels are usually better for long term storability of the bale, so there is no heating of the bale and mold is less of an issue. Waiting for the moisture to decrease though can reduce the amount of time available for baling. For example, Schechinger and Hettenhaus (1999) reported that at 20% moisture there were 54 hours of baling time in 12 days of fall harvest. When moisture was 24% there were 74 hours to bale in 16 days and at 30% moisture there were 150 hours for baling over 18 days. The increased moisture, particularly over 24%, allows a much wider window for baling in the fall period if the product quality is still acceptable to the end user. There is emerging information from equipment manufacturers in the U.S. that will test windrowing stover at the time of combining the grain. If this is successful, it could help with drying the stalks and reducing capital and operating costs.

Related to moisture content is the amount of equipment required. There is an important difference in equipment requirements depending on the acceptable moisture content of the stover and the number of fall harvest days available. This is highlighted in Table 3 which shows the estimated number of each type of equipment that is required for each harvest day length. The capital investment in equipment and the estimated labour requirements for each harvest length is shown in Table 4.

Table 3. Total Equipment Needed for 250,000 tonnes Corn Stover Harvest

Variable	Collection Required (ac/hr)	Disc Mowers	Wheel Rakes	Balers	Tractors
30 harvest days	947	118	118	79	363
40 harvest days	710	89	89	59	272
50 harvest days	568	71	71	47	218

Source: University of Guelph, Ridgetown Campus calculations based on information from Hettenhaus et al., 2009 and Ontario custom operators. Note: 10 hours/day.

Table 4. Capital and Staffing Levels Needed for 250,000 tonnes Corn Stover Harvest

Variable	Total Equipment Cost	Staff (+15% support)
30 harvest days	$67 mill	418
40 harvest days	$50 mill	313
50 harvest days	$40 mill	251

Source: University of Guelph, Ridgetown Campus calculations based on information from Hettenhaus et al., 2009 and www.caseih.ironbuilder.com. Note: An additional 15% staff are included to account for administrative and management support.

3.0 - Pricing Corn Stover

No formal commodity market structure currently exists where stover is actively bought and sold unlike for other commodities such as grain corn, soybeans, wheat, etc. POET-DSM is reportedly offering $55/ton ($60/tonne) for corn stover delivered to their cellulosic plant in Emmetsburg, Iowa (Lane, 2013). Producers are responsible for harvesting the biomass either using their own equipment or having it custom done and delivered to the plant. POET has a producer handbook that outlines specifications regarding harvest, bale size, storage methods, delivery, penalties, etc. (POET-DSM). Furthermore, producer support is available through an equipment dealer as well as extension personnel.

There are several ways that corn stover can be potentially valued. These range from harvest cost plus nutrient replacement to prices offered by an end user (e.g. feed replacement, wheat straw replacement, etc.).

3.1 Harvest Cost Plus Nutrient Replacement

With this pricing method, the price of stover would cover the cost of harvesting plus the value of nutrients that are removed in the stover. Most pricing models identify a specific fee structure that takes into account some or all of the following costs: stalk chopping, raking, baling, nutrient replacement, and moving bales to end of the field. Sometimes producers may also incur costs to transport bales to central storage locations or to an end-user. The activities will depend on the process used and when ownership of the stover changes hands.

Several cost estimates reported in the literature are compared in Table 5. Most of these assume corn stover is harvested for a biorefinery. It should be noted that five of the sources cited in Table 5 are from the U.S. and two are from Ontario. Every attempt has been made to allocate the costs as accurately as possible for comparison purposes and the values have been converted to 100% dry matter and $CDN/tonne assuming an exchange rate at par ($1US = $1CDN). Two prices are highlighted. One is termed “farm-gate” price while the other is the “delivered” price. Although the sources shown in Table 5 did not always provide values for all of the costs, they provide a starting point for discussion. The majority of the farm-gate values fall in the $50 to $70/dry tonne range. Table 5 highlights the wide differences in costs when using different sources and time periods which range from 2002 to 2012. This is partly reflective of factors such as local supply and demand conditions with respect to field operations, fertilizer prices, and distance to market.

Values for harvesting activities (i.e. shredding, raking and baling) are shown for all sources and most total harvest costs are in the $25 to $30/tonne range. There is a wide range of values within each individual cost category. Differences in the values are due to assumptions used for the type of equipment used and the value of the equipment as well as project efficiencies with respect to the amount harvested per acre or total project volume required.

There is much debate about the harvest activities that are needed. For example, the weather at time of harvest may determine whether there is a need for shredding or if it is possible to just rake and bale the stover. If shredding or stalk chopping is unnecessary, costs could be reduced by approximately $5/tonne. Another

Table 5. Sample Costs – $CDN/tonne at 100% Dry Matter

Source	Morey et al. (2010)	Hart & Edwards (2012)	Thompson & Tyner (2011)	Perlack & Turhollow (2002)	Hess et al. (2009)	Oo, Albion et al. (2012)	McDonald (2010)
Geographic location of sample costs	U.S. Average/Model	Iowa	Iowa	US Average/Model	U.S. Average/Model	Ontario	Ontario
Shred	2.99	6.34				7.41	4.83
Rake	1.81	3.55		28.80	4.58	3.46	
Bale	24.89	26.41	22.76		12.02	19.04	22.05
Transp to field edge/local storage	6.48			7.91	7.21	4.76	5.50
Storage	3.81		21.35		8.94	6.50	4.00
Nutrient replacement	22.66	18.60	24.79				32.36
Payment to farmer	8.82			11.02	17.52		
Total farm-gate	**71.46**	**54.90**	**68.90**	**47.73**	**50.27**	**41.17**	**68.74**
Transp to end user	8.30[1]	11.48	34.02[2]		13.15	25.00	
Total delivered to end user	**79.76**	**66.38**	**102.92**	**47.73**	**63.42**	**66.17**	**68.74**
Notes	70% residue removed every other year; 5.6 km round-trip to local, uncovered storage; to end-user round-trip 84 km	1.09 tonnes/acre; 20 mi transport to end user	33% residue removed/year; Storage includes cost of land, rock, tarps on farm up to 1 year; end user 50 mi radius	33% residue removed/year; Payment to farmer = nutrient replacement and potential soil compaction; Includes 5% administration charge. Storage 3.1-8.7 mi away. Costs based on 500 ton/day facility.	38% residue removed/year; Dry matter loss of 5% harvesting & collecting and 5% in storage; Stored in plastic wrap on farm or less than 5 mi away; 37.8 mi to end-user	2 tonnes/acre; store unwrapped bale under tarp on farm; 150 km to end user	

Numbers may not add due to rounding.
[1] Stover is pre-processed at local storage site prior to delivery to end-user. Pre-processing costs are not included but transportation cost is for compacted stover.
[2] Includes $8.17 to load bales from field and unload bales at end-user plus $25.86 transportation to end-user.

option is to add an attachment to the combine that will shred the stover as the grain is harvested. Although this means one less pass of the field for shredding, the cost of the attachment would need to be taken into consideration.

The value for baling varies considerably from \$12/tonne to \$26/tonne in Table 5. With a difference of \$14/tonne, this is one area that should be explored to determine the most efficient baler and stover harvest removal rate to undertake.

The cost to move bales to the edge of the field or to a local central storage site was included by most sources in Table 5. In general, this cost amounted to about \$6 to \$7/tonne. The storage method commonly used was to place the bales in a location that was well-drained and either leave the bales uncovered or cover them with a tarp. Thompson and Tyner further indicated that the on-farm storage location would have the stacked bales placed on crushed stone where they would be tarped and the storage cost took into account the value of the land. This resulted in a much higher (i.e. \$21.35/tonne) cost for storage than the other sources. It should be noted that for the purposes of this Southwestern Ontario project, limestone would be the preferred material used rather than crushed stone. Although storage costs have not been reported for the POET project, their producer handbook outlines recommendations for storage such as being on level, well-drained ground, the stack heights/sizes/spacing configurations for round and square bales and whether or not to tarp the bales depending on the length of time the bales will be stored. There is no penalty for bales with moisture content up to 35%.

The value of nutrient replacement can represent a significant part of the total corn stover cost. There are difficulties associated with placing a value on nutrients that are removed. The literature suggests that there should be some compensatory value but the amount depends on factors such as how much is in the stover (actual versus estimated), the time of year the stover is harvested (leaching of nutrients occurs over time), how much of the nutrients are actually available or will be used by the next crop, commercial fertilizer prices, etc. Stewart (2011) indicated the value of nutrients removed in corn stover in Ontario could have been \$22.73/tonne to \$34.09/tonne simply due to different fertilizer prices. While there is some debate about whether nitrogen should be included in the nutrient replacement value depending on crop rotation (Milhollin et al.; Petrolia; Rankin; Brechbill and Tyner; Hart and Edwards; Hess et al.; Morey et al.) it is widely accepted that phosphorus and potassium should be included. In Table 5 for those that provided nutrient replacement values, the amounts ranged from \$18.60/tonne (Hart and Edwards) to \$32.36/tonne (McDonald).

Perlack and Turhollow and Hess et al., however, included an amount for nutrients in the “payment to farmer”, \$11.02 and \$17.52/tonne respectively. Perlack and Turhollow suggest that producers should receive not only the cost of the nutrients removed but also an amount to cover potential compaction and effect on soil organic matter. To encourage producer motivation to participate in supplying biomass, different methods have been suggested. Some of these methods are intended to include an implied profit to the producer. In Table 5 Morey et al. includes a payment to farmer of \$7.50/tonne in their model. Brechbill and Tyner (not included in Table 5) suggests a premium of 15% of the biomass cost and Petrolia (2008) states that producers need to be compensated for the nutrients removed in the stover plus an extra amount to reflect local conditions. Literature reviewed by Milhollin indicates that producers should receive 10% to 15% of total product cost to encourage participation.

In summary, Table 5 shows that the farm-gate value of stover ranges from approximately $50 to $70/dry tonne depending on the variables included. Without nutrient replacement, the range is about $36 to $49/dry tonne.

When transportation to an end-user is included, an additional cost of about $8 to $34/tonne is required to deliver the corn stover depending on the distance and activities included in the cost estimates. It is important to note that Morey et al. assume that the stover is pre-processed at the local storage sites. Regardless, transportation represents another key cost component. Location of the end user close to where the corn is produced would help decrease this cost as well as long-term/volume contracts with transportation companies. It is anticipated that an end-user would have the equipment necessary to unload the bales quickly and efficiently.

According to Table 5 the total cost of stover delivered to the end-user is approximately $63 to $103/dry tonne depending on the harvest activities required, storage expectations and distance to end-user. Recall that the values in Table 5 are based on various points in time ranging from 2002 to 2012. It should be noted that the Statistics Canada Farm Input Price Index (FIPI) for Ontario increased 39 per cent from 2002 to 2012.

It is important to highlight that there is a website that has a feedstock cost and profitability calculator (http://miscanthus.ebi.berkeley.edu/biofuel/) developed by Khanna and Huang (2010). Although it is specific to certain locations in the U.S., all of the variables can be changed so that the users can input their own farm data with respect to yields, expenses and revenues. A sensitivity analysis provides an opportunity to make adjustments to some variables and understand the impacts these changes could have on profitability. This tool can be helpful to Ontario producers if they know their costs. Again, the baseline data is based on U.S. values and will be different from Ontario values.

3.1.1 Ontario Stover Pricing Based on Harvest Costs plus Nutrient Replacement

Table 5 is mostly based on U.S. data (except for the costs shown for Oo, Albion et al. and McDonald) and the estimates vary depending on what cost items are included. Much of the U.S. data is based on models and some of the numbers are several years old which can have a substantial impact on fertilizer values. Table 6 is an attempt to determine costs for Ontario stover. Some of the differences between the U.S. and Ontario figures might be accounted for on the basis that U.S. researchers may have had a better handle on their costs; or there might be economies of scale; or it may depend on a difference arising from using older versus newer harvest equipment; or the U.S. figures are based on harvesting more stover/acre than the assumptions used in calculating the Ontario costs in Table 6. The difference in grain corn yields between Iowa and Ontario may enable Iowa producers to harvest more stover.

Estimates of Ontario corn stover harvest, nutrient removal, storage and transportation costs for 2003 to 2012 are shown in Table 6 on a 100% dry tonne basis. The term “discbine” refers to the machine used to shred or chop the corn stover. Discbine, raking and baling costs for 2012 were based on discussions with Ontario custom operators. These costs were then adjusted for 2003 to 2011 using the Statistics Canada Farm Input Price Index (FIPI). OMAF’s Custom Farm Rates for 2012 were also consulted.

Harvest costs range from $56 to $78 per dry tonne. Storage costs increased from $5.74 to $8.00/dry tonne. Storage at end of the field assumes bales are stacked in a well-drained location and covered with a tarp. Storage and transportation prices have also been adjusted using the Farm Input Price Index. It is assumed that the stover is transported an average 75 km with the costs ranging from $11 to $16/dry tonne over the 10 year time period. The average distance between Sarnia and the five producer focus meeting locations (Wyoming, Appin, Strathroy, Lucan and Ridgetown) is 75 km. Therefore, it was assumed that the majority of stover would be procured within this average distance. In an effort to reduce transportation costs, it is likely that an increased effort to procure corn stover located closer to Sarnia would be the ideal.

With the Ontario costs in Table 6, conservative figures were used as this is a relatively new concept for Ontario. It is unknown how much wear and tear will occur with equipment harvesting stover as compared to harvesting wheat straw or hay. One of the important questions related to the harvest costs is if a discbine is needed for shredding/chopping the corn stalks. This is a large expense at approximately $18/acre. Ontario producers/custom operators have not had much opportunity to work with stover on a large scale which contributes to the unknown about what harvest activities are needed and what equipment wear and tear will result. This concern has been identified by equipment manufacturers and more robust equipment lines are being introduced to handle stover.

Nutrient costs for nitrogen (N), phosphorous (P) and potassium (K) removed in the stover are based on OMAF's nutrient management program and NMAN calculator. The assumptions used are the approximate amounts of each nutrient assumed to be available to the next year's crop if the stover is left in the field. For nitrogen this amount is 25%, phosphorous is 40% and potassium is 90%. The nutrient content in each tonne of stover removed from the field is based on Ontario field trial data from Agris Co-op conducted as part of this project. The assumptions used are 8.2 kg of N, 1.9 kg of P and 7.4 kg of K per dry tonne. Nutrient costs in Table 6 show variability because annual fertilizer prices have fluctuated considerably over this time period. Nutrient replacement costs ranged from $5/tonne to $15/tonne of stover removed.

It is estimated that the total cost per tonne of stover removed would be approximately $98/tonne at the farm gate for 2012 with a ten year average of $82/tonne. When transportation is added, the estimated total cost per tonne of stover delivered to the end user would be approximately $114/tonne for 2012 with a ten year average of $96/tonne. It should be noted that these costs do not include a profit to the stover producer. They only reflect the costs to harvest, store and transport the stover.

From an end users' perspective, there are two additional factors that need to be taken into consideration with respect to the price they are willing to pay for the stover. The moisture content of the bale can affect the quality or quantity of the end product, and the ash content (the level of foreign material such as dirt and stones) can cause damage to processing equipment. It is uncertain at this point if a bale treatment such as propionic acid would be beneficial for maintaining stover bale quality during storage. The estimated cost for this would be approximately $8/tonne and is not included in Table 6.

Two examples of quality assessment parameters are provided in Table 7. The first set is from POET's producer handbook and shows that bales with up to 35% moisture and up to 15% ash have no penalty. In research completed by Thompson and Tyner, less than 20% moisture and less than 10% ash would be acceptable before a penalty is assessed.

Table 6. Stover Cost Based on Harvest Costs, Nutrient Replacement, Storage and Transportation Costs ($/dry tonne)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Discbine ($/acre)	12.91	13.17	13.74	14.03	14.85	16.46	16.12	15.75	17.12	18.00
Raking ($/acre)	5.74	5.86	6.11	6.24	6.60	7.32	7.16	7.00	7.61	8.00
Baling ($/acre)	27.23	27.79	28.99	29.61	31.34	34.72	34.00	33.23	36.11	37.97
Stacking at end of field ($/acre)	3.40	3.47	3.62	3.70	3.92	4.34	4.25	4.15	4.51	4.75
Sub-total – harvest costs ($/acre)	49.28	50.30	52.47	53.58	56.71	62.84	61.53	60.14	65.34	68.72
Sub-total – harvest costs ($/tonne)	56.00	57.15	59.61	60.87	64.43	71.39	69.91	68.32	74.24	78.08
Nutrient costs ($/tonne)	5.37	5.56	6.32	6.83	7.23	13.01	15.48	9.25	11.06	12.25
Storage costs-end of field ($/tonne)	5.74	5.86	6.11	6.24	6.60	7.32	7.16	7.00	7.61	8.00
Corn Stover Cost – farm gate ($/tonne)	**67.10**	**68.56**	**72.04**	**73.94**	**78.26**	**91.71**	**92.56**	**84.58**	**92.91**	**98.32**
Transportation to end user ($/tonne)	11.45	11.69	12.19	12.45	13.18	14.60	14.30	13.97	15.18	15.97
Corn Stover Cost – delivered ($/tonne)	**78.55**	**80.25**	**84.23**	**86.39**	**91.44**	**106.31**	**106.85**	**98.55**	**108.09**	**114.29**

Assumptions: 165 bushel/acre grain corn yield; 0.88 dry tonne/acre stover harvested; 30% stover removal rate; 30% moisture content; Nutrient removal per tonne = 8.2 kg N, 1.9 kg P, 7.4 kg K.
Sources: Industry sources; OMAF; Oo et al., 2012; University of Guelph, Ridgetown Campus

Table 7. Quality Assessments For Stover

1	Moisture	Dockage	Ash	Dockage
	0 – 35%	$0	0 – 15%	$0
	35 – 50%	$5/BDT	15 – 25%	$10/BDT
	50%+	Rejected	25%+	Rejected
2	**Grade**	**Moisture**	**Ash**	**Penalty**
	1	< 20%	< 10%	$0
	2	20% and < 28%	< 15%	$8/ton
	3	28% and < 36%	< 15%	$17/ton
	4	36%+	> 15%	100% of price

Note: BDT = bone dry ton (i.e. 100% dry matter content)
Source: POET-DSM Project LIberty Biomass Producer Handbook; 2 Thompson & Tyner, 2011

3.2 Stover Pricing based on Feed Replacement Value

Another option for pricing stover is from Edwards (2011) at Iowa State University (ISU). The ISU Ag Decision Maker program has a model that prices stover based on feed replacement value. This means that corn stover could replace hay, for example, in a feed ration. In this scenario, dried distillers grains (DDG) would need to be added as an energy source. The volume and price of hay being replaced represents the maximum price that a buyer of feed might pay, and substracting the cost of the DDG.

The following is an example using 2012 Ontario values that is based on the Ag Decision Maker program and how this would potentially work if a corn producer is selling stover to a feed user (e.g. beef feedlot). If 1 tonne of corn stover replaces 1.16 tonnes of hay and the market price for hay is $186/tonne, then 1 tonne of stover would be $215.76 (1.16 x $186 /tonne). Subtracting the cost of 0.22 tonnes of DDG (0.22 tonnes x $259.54/tonne for DDG = $57.10) from this would mean the stover would be valued

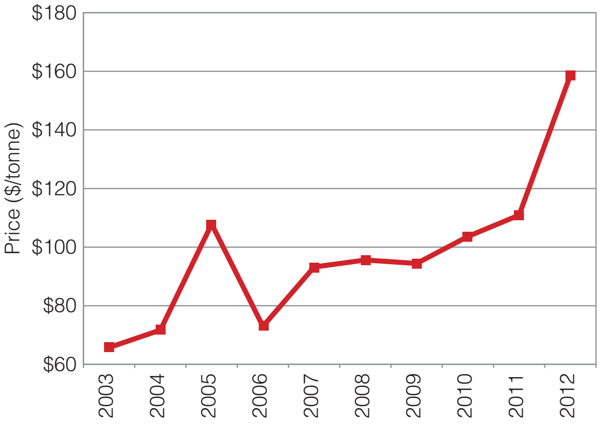


Figure 8. Estimated Feed Replacement Value for Corn Stover, 2003 to 2012 ($/tonne)

Source: University of Guelph, Ridgetown Campus calculations based on information from Farm Market News, OMAF, Agricorp, and Iowa State University.

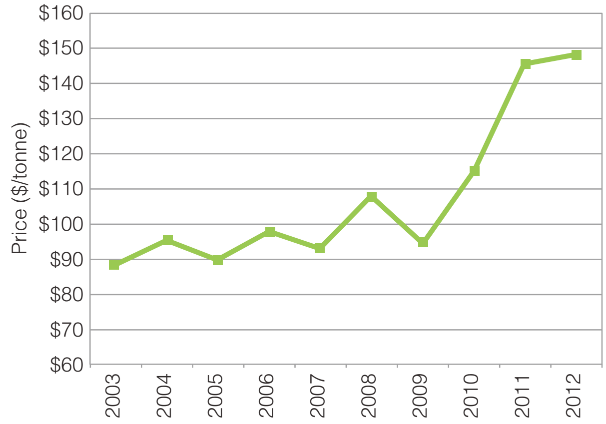


Figure 9. Value Of Wheat Straw, 2003 to 2012 ($/tonne)

Source: OMAF; Agricorp.

at $158.66/tonne. There is no transportation taken into account in this example. The value is assumed to be the on-farm price of stover and the buyer would have to arrange and pay for transportation to move the stover. To transport biomass 100 km costs approximately $19.39/tonne (Oo et al., 2012). With respect to estimating a nutrient replacement value for the corn producer when the stover leaves the farm, it is assumed that the value received for the stover will cover the cost of replacing the nutrients with commercial fertilizer. Figure 8 shows the estimated feed replacement value for corn stover in Ontario from 2003 to 2012 based on historical hay and DDG prices. The ten year average was $97/tonne and ranged from $66 to $159/tonne.

3.3 Stover Pricing based on Wheat Straw Value

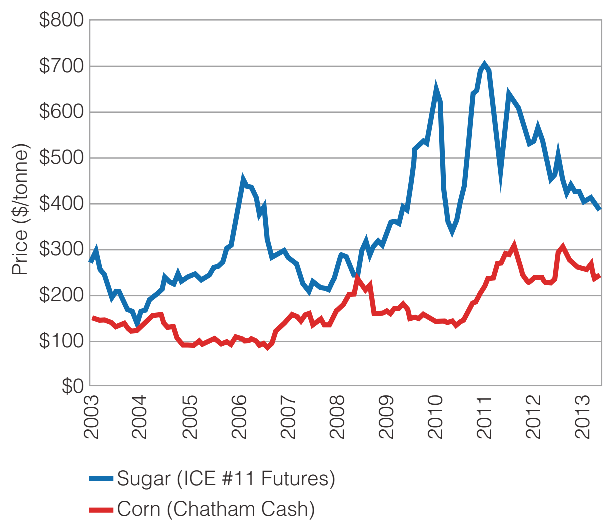
The price of corn stover can also be determined relative to the price of straw (e.g. wheat, oat, barley). Corn stover can be used as an alternative to straw in livestock feed rations and also as bedding for livestock. It is similar to corn in terms of cellulose and hemi-cellulose composition (Lee et al., 2007). Figure 9 shows the value of wheat straw in Ontario from 2003 to 2012. Based on the annual fair market value reported by Agricorp, the value of straw ranged from $89 to $149/tonne and the average was $108/tonne. This is the on-farm price and does not take into account the cost of transportation to an end user. It costs approximately $19.39/tonne to transport biomass 100 km (Oo et al.).

3.4 Stover Pricing based on Value of Further Processing Bioproducts

Formulas or methods for pricing stover based on the value of bioproducts obtained from further processing could potentially be used. These bioproducts include cellulosic ethanol that is sold for transportation fuel, and cellulosic sugars that are further converted into higher value chemicals. These pricing formulas would need to be transparent, easy to understand, and acceptable to all value chain participants. For this project, the goal is for corn stover to be processed into cellulosic sugars and lignin. These cellulosic sugars are intermediate products that could then be used as an input to produce biosuccinic acid, for example. They could be a substitute for corn glucose. Prices for sugar (i.e. corn glucose) from other sources provides a ceiling for stover values based on sugar content. The lignin can be converted into higher value chemicals or burned for energy. Further discussion on estimating a value for corn stover based on the yield of cellulosic sugars is contained in the Potential Business Models section later in this report.

3.5 Corn and Sugar Price Volatility

As a comparison of the price volatility in the corn and sugar markets, Figure 10 shows monthly ICE Contract #11 nearby futures world raw sugar prices and Chatham cash corn prices in $C/tonne from January 2003 to May 2013. Although the ICE contract represents a world benchmark price and would need to be adjusted to account for local market conditions, it is reflective of trends in the sugar market. Both corn and sugar prices have experienced much variability during this time period. This indicates that both corn producers and sugar producers face potentially large price fluctuations with their products due to supply and demand conditions as well as market speculation. The correlation between the two price series is 0.55 which means that the two prices do not necessarily move in the same direction and magnitude at the same time. This is an underlying reason why corn stover is considered an attractive option since there is a plentiful supply. Also, if it can be obtained at a relatively stable price over time, corn stover provides a narrower band on input costs for sugar producers. For corn producers, this new market will help with grain price fluctuations.



Sugar Prices

Jan. 2003-May 2013	Average = $361/tonne Standard Deviation = $144/tonne
Jan. 2008-Dec. 2012	Average = $462/tonne Standard Deviation = $130/tonne

Corn Prices

Jan. 2003-May 2013	Average = $167/tonne Standard Deviation = $59/tonne
Jan. 2008-Dec. 2012	Average = $204/tonne Standard Deviation = $52/tonne

Figure 10. Monthly Sugar and Corn Prices, January 2003 to May 2013 ($C/tonne)

Source: USDA; ICE; Bank of Canada; Farm Market News, University of Guelph, Ridgetown Campus.

4.0 Business Structures for New Value Chain

There are various business structures that can be considered when starting a business. A brief synopsis of these structures is provided below, however, prior to establishing a business financial and legal advice should be obtained. The information contained herein is not intended to be an exhaustive resource but to provide a very basic and general overview.

Sole proprietorships and partnerships are more often used when the business venture is relatively small. A sole proprietorship is easy and inexpensive to establish. A partnership is also fairly easy to start. In a sole proprietorship there is only one owner, and that person is liable for all debts incurred by the business and personal assets may be used to meet these obligations if necessary. In a partnership the partners are liable for all debts, similar to a sole proprietorship, and personal assets may be used to cover these debts. In a partnership, it is important to have partners that are able to work together and possibly bring complementary skills to the business.

A corporate or co-operative (co-op) business structure would be more attractive for a cornstalks to biochemical project because liability is limited and it may be easier to raise large amounts of capital. Table 8 provides a brief comparison between these two models. One difference is with respect to voting. The co-op structure is based on one member, one vote regardless of the number of shares a person has compared to the business structure where the number of shares a person holds represents the number of votes they are entitled to. Another key difference is that a co-op's mandate is to sell goods or services to members and/or buy products from the members.

Table 8. Co-op versus Business Corporation

	Co-op	Business Corp
Ownership	5+ members	1+ indiv/corp
Voting	1 member = 1 vote	# shares held = # votes
Shares	Little/no change in value, redeemed only	Value can change, can be sold
ROI	Patronage dividend in proportion to use of co-op	Dividends based on # of shares
Liability	Limited to investment, Directors can be liable	Limited to investment, Directors can be liable

Source: Ontario Co-operative Association, AAFC, OMAFRA

There are six types of co-operatives and they are listed below with a brief description of what they do:

1. Consumer co-op – provides goods/services to members
2. Producer co-op – sells goods/services produced by members and/or supplies products/services to members
3. Worker co-op – provides employment for members
4. Multi-stakeholder co-op – members share a common interest; could be employees, clients, other individuals or organizations
5. Service co-op – provides services to members
6. Financial co-op – provides financial, investment or insurance services to members

Source: Agriculture and Agri-Food Canada

Many Ontario farmers may be members of co-ops and some co-ops include the following: Agris Co-operative Ltd., IGPC (Integrated Grain Processors Co-operative Inc.), Michigan Sugar Company, Conestoga Meat Packers, Hensall District Co-operative, Gay Lea Foods Co-operative Limited and so on. Being part of a co-op can provide members with an opportunity to be further involved in the value chain through dividend payouts. Table 9 provides information on four co-ops and estimates of the number of members, sales, initial member investments, members' equity and so on.

Table 9. General Information on Four Agricultural Co-ops

	Agris (2006)	Michigan Sugar (2002)	IGPC (2002)	Conestoga (2001)
Members	2,500	1,000	900	150
Sales	$217 M[a]	$549 M[b]	$110 M[c]	$130 M[c]
Assets	$57 M[a]	$256 M[b]	$122 M[c]	$34 M[c]
Members Equity	$16 M[a] (28%)	$29M/$63.5M[d] (46%)	$54 M[c] (44%)	$13 M[c] (38%)
Initial member investment	$1,000 (40 shares)	$200 / acre	$500 (5 member shares) $5,000 (1,000 shares)	$200 (2 member shares) $20 / hog
Product volume (Members %)	Crop inputs Grain	3.9 million tons sugar beets (100%)	16 million bu. Corn (8%)	750,000 hogs (100%)
Return to member	- dividends - purchase power	- company returns - sugar content	- dividends - market price	- company returns - pork quality

Source: Based on information obtained from various industry sources and estimates by University of Guelph, Ridgetown Campus.
Notes: [a] 2012; [b] 2011; [c] 2009; [d] 2002 – at time of initial purchase

5.0 Potential Business Models

A main objective of this project is to discuss various potential business models and pricing options that could be used in a cornstalk to bioprocessing venture that converts 250,000 dry tonnes of corn stover. Four models will be discussed and they are listed below.

1. Direct sale – corn stover producer sells stover directly to cellulosic sugar company
2. Request for purchase (RFP) – cellulosic sugar company requests a RFP to aggregators to provide stover
3. Supply co-op – corn stover producers form a co-op that may contract out harvesting activities, and/or owns stover harvesting equipment, retains labour for harvesting, manages logistics, etc. and then sells stover to the cellulosic sugar company. Corn stover producers may also perform the harvest activities with their own equipment.
4. Bioprocessing co-op – a co-op comprised of members that may include corn stover producers, custom operators, aggregators, transporters, cellulosic sugar company, and biochemical companies.

From producers' perspective, it is important that they are compensated for the costs they incur harvesting the stover, for nutrients that are removed, and for potential negative impacts on their land, liability, insurance, etc. The activity has to generate profits and not take away from the use of the land (e.g. next crop planting, long term soil productivity, etc.). Participants at the Ontario focus group meetings stressed these factors. A key requirement for the cellulosic sugar company is the ability to source a sufficient amount of biomass of a consistent quality on an ongoing basis at a cost that is economical. The numbers used in the discussion below are based on various literature sources and personal communication with industry stakeholders.

5.1 Direct Sale

With a direct sale approach, the corn producer sells stover directly to the sugar company. The farmer would be responsible for harvesting, storing and transporting the stover to the sugar company. The actual harvesting of the stover could be done by the corn grower or hired out to a custom operator. The price paid to farmers for the stover would have to be comparable to competing uses for stover such as livestock bedding or feed.

From the sugar company's perspective, the largest obstacle with this model is that they would not be guaranteed a supply of stover, particularly over the long term. Producers would seek out the highest bidder or they may simply choose not to harvest the stover some years. Producers would need to feel they are compensated fairly; however, it is uncertain what stover value would secure their participation over the long term.

Cost estimates discussed previously in Table 6 are shown again in Table 10. The stover cost in Table 10 is based on harvesting and storage costs, nutrient replacement, transportation to processor, and includes a value for production management issues not included in Table 6. The production management issues cost value is 15% of harvest costs, nutrient replacement and storage and is intended to cover such things as potential compaction and rutting of fields, erosion, bale shrinkage/loss, and liability. Producers at the focus group meetings expressed much concern about these issues. With the production

Table 10. Direct Sale Pricing Option – Stover Cost Estimates ($/dry tonne)

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Discbine ($/acre)	12.91	13.17	13.74	14.03	14.85	16.46	16.12	15.75	17.12	18.00
Raking ($/acre)	5.74	5.86	6.11	6.24	6.60	7.32	7.16	7.00	7.61	8.00
Baling ($/acre)	27.23	27.79	28.99	29.61	31.34	34.72	34.00	33.23	36.11	37.97
Stacking at end of field ($/acre)	3.40	3.47	3.62	3.70	3.92	4.34	4.25	4.15	4.51	4.75
Sub-total – harvest costs ($/acre)	49.28	50.30	52.47	53.58	56.71	62.84	61.53	60.14	65.34	68.72
Sub-total – harvest costs ($/tonne)	56.00	57.15	59.61	60.87	64.43	71.39	69.91	68.32	74.24	78.08
Nutrient costs ($/tonne)	5.37	5.56	6.32	6.83	7.23	13.01	15.48	9.25	11.06	12.25
Storage costs-end of field ($/tonne)	5.74	5.86	6.11	6.24	6.60	7.32	7.16	7.00	7.61	8.00
Production management issues ($/tonne)	10.07	10.28	10.81	11.09	11.74	13.76	13.88	12.69	13.94	14.75
Corn Stover Cost – farm gate ($/tonne)	**77.17**	**78.85**	**82.84**	**85.03**	**90.00**	**105.47**	**106.44**	**97.27**	**106.85**	**113.07**
Transportation to end user ($/tonne)	11.45	11.69	12.19	12.45	13.18	14.60	14.30	13.97	15.18	15.97
Corn Stover Cost – delivered ($/tonne)	**88.62**	**90.53**	**95.04**	**97.48**	**103.18**	**120.07**	**120.74**	**111.24**	**122.03**	**129.04**

Assumptions: 165 bushel/acre grain corn yield; 0.88 dry tonne/acre stover harvested; 30% stover removal rate; 30% moisture content; Nutrient content per tonne = 8.2 kg N, 1.9 kg P, 7.4 kg K. Production management issues = 15% of harvest, nutrient, and storage costs.
Sources: Industry sources; OMAF; Oo et al., 2012; University of Guelph, Ridgetown Campus.

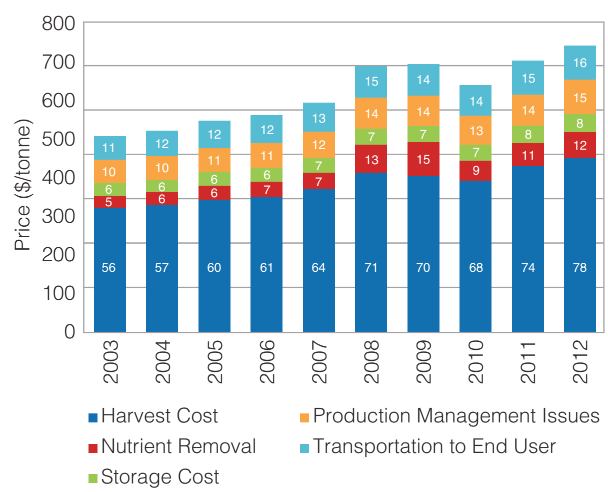
management value included, the stover would cost approximately $129/tonne for 2012. The ten year average from 2003 to 2012 was estimated at $108/tonne and ranged from $89 to $129/dry tonne. Again, it is important to note the variability in the cost estimates that is attributed to changes in fertilizer prices. Nutrient costs ranged from $5 to $15/tonne of stover.

Harvesting corn stover on a large scale is relatively new but improved technologies and systems will help reduce costs over time.

The corn stover cost estimates ($/tonne) are shown graphically in Figure 11.

Wet weather experienced during the fall harvest of 2012 would cause some producers to reconsider selling their stover if they didn't feel the return was enough to justify potential negative impacts on their land (i.e. compaction and rutting during stover harvest). Another way to secure a sufficient quantity of stover would be to have long-term contracts with individual producers, but for a large project it would require managing contracts with many producers. This is disadvantageous for a bioprocessor unless they have staff dedicated to this role. For these reasons this business model is an unworkable option for this type of project.

Figure 11. Direct Sale Pricing Option – Corn Stover Cost Estimates ($/dry tonne)



5.2 Request for Purchase

In this type of business model aggregators are considered to be individuals or businesses that source biomass from producers. They harvest the stover, stack the bales in an accessible location and when needed, transport them to the processor. They would own harvesting equipment such as rakes and balers, have access to labour to operate the equipment in a timely manner and either own transport trucks to haul the biomass to the processor or contract out the transportation. An aggregator may need a person dedicated to sourcing the biomass and testing it for quality purposes, an office assistant and a manager to oversee the business.

The pricing methodology for this business model might be similar to the direct sale model. Aggregators would be required to submit tenders to provide stover to the cellulosic sugar company; therefore, it is unknown at what price level they would bid. The price level would be directly related to the volumes they bid on, their costs, etc.

This method has some challenges. One challenge is the short harvest window and another is the need for labour skilled in operating harvesting equipment. Corn stover harvest occurs at the same time as grain corn harvest, so aggregators will already be busy. Hiring additional labour for the stover harvest may be possible to an extent but will likely be difficult to hire sufficient numbers of qualified people for such a short period of time. Also, transportation is another potential problem because the harvesting of cash crops such as soybeans, corn, sugar beets, etc. will be competition to the stover project. It may be possible, however, to have a contract with a trucking firm to be the exclusive, year-round transporter for the stover, and this could potentially result in lower overall transportation costs.

Another challenge is the sourcing of the required amount of corn stover. Similar to the first pricing option, farmers may be reluctant to sell their stover to the aggregator or commit to selling over the long term.

With respect to capital investment in terms of harvesting equipment (i.e. rakes, balers, etc.) there would be significant costs to acquire the equipment needed. However, it is possible to use this equipment for other crops such as wheat, hay, oats, etc. and spread the costs over more acres.

From the end user's perspective, this option may be more attractive because they would contract with a small group of aggregators rather than a large number of farmers. However, a project of any significant size would need a long-term, guaranteed supply of corn stover and with this option, achieving this may still be difficult. Farmers would either sell to the highest bidder or perhaps not sell at all. The discussion at the focus meetings showed that farmers do not want to simply sell their stover as a commodity. Rather, they want to be part of the value chain. Also, they are concerned about who will be on their land during harvest and want to be involved in the process.

5.3 Supply Co-op

In a supply co-op model, the co-op acts as an aggregator and sources the stover and sells it to the sugar company. This is similar to the previous model except the stover producers are members of the co-op. Producers could purchase membership shares (e.g. priced per acre or tonne of stover to be supplied). This assures a stover supply for the co-op and in turn, the end user(s). Stover producers could potentially benefit by moving up the value chain. Custom operators, aggregators and trucking firms could also be members of the co-op.

A financial model has been created to analyse this option. The model calculates the Return On Investment (ROI) for the sugar company assuming that the supply co-op sells the stover at full cost to the sugar company. The financial assumptions that have been used in the analysis are shown in Table 11. This is used as the base case. The corn yield is based on the annual averages for 2008 to 2012 for the four counties of Lambton, Huron, Middlesex and Chatham-Kent. It is recognized that in lower yielding fields harvesting stover from a conservation perspective (i.e. less than 150 bu/ac corn) is undesirable and on high yielding fields, harvesting more than 0.88 dry tonnes/acre may be possible. Once a project such as this begins, it will be important for site-specific harvest rates to be determined.

The harvest costs in Table 11 are based on OMAF Custom Rates and discussions with custom operators. Custom rates are used as a proxy for the cost of owning equipment and the associated operating costs. It is possible that improved technologies and volume discounts resulting from acreage discounts could reduce some of these costs in the future. However, if the co-op wants to own equipment, Table 12 below details estimated requirements based on harvest period available.

Table 11. Assumptions Used in Financial Analysis

Variable	Value
Grain corn yield	165 bu/ac
Stover moisture	30%
Stover removal rate	30%
Stover removed	0.88 dry tonnes/ac
8x4x3 foot bale weight	371 kg
Harvest costs	**$/dry tonne**
Discbine/stalk chop	20.45
Rake	9.09
Large square baling	43.14
Stack end of field	5.39
Storage end of field	8.00
Nutrient replacement	11.57
Production management issues (15%)	14.65
Transportation 75 km	15.97
Administration	1.00
Stover cost sub-total	129.27

Note: These assumptions are based on consensus from the advisory committee after discussing data from literature and industry sources.

Storage is assumed to be at the end of the field with the bales tarped. Nutrient costs are based on 2013 fertilizer values and the estimated percentage of nutrients that would be available to the next year's crop if the stover was left in the field according to NMAN assumptions.

Production management issues have been defined previously in section 5.1 (eg. potential compaction and rutting of fields, erosion, bale shrinkage/loss, and liability). It is expected that there would be administration expenses to address the co-op's cost for logistics, contract management, managing the stover supply, payment to producers, etc. It is assumed that this would be approximately $1.00/tonne and is included in the cost of the stover.

A supply co-op may want to invest in harvest equipment in order to have some control over this activity; however, this has not been included. If this is done, it would be also important for the co-op to use the equipment at other times of the year to spread the cost over more acres. Table 12 illustrates the estimated equipment and staff requirements to harvest 250,000 dry tonnes of corn stover from 284,000 acres (assuming 0.88 tonnes of stover/acre) based on the number of fall harvest days and hours available. Harvest days and hours available will vary considerably based on field conditions and acceptable moisture level at time of harvest. For example, if 30 harvest days (300 harvest hours) are available, then approximately 947 acres/hour would need to be harvested. This would require 363 equipment operators and 55 support staff (i.e. field advisors, management, administrative). Equipment requirements would involve approximately 118 discbines/stalk choppers, 118 rakes, 79 square balers, and 363 tractors. If all this equipment is purchased new, the approximate cost would be $67 million. In reality, harvesting of the corn stover would likely be achieved through a combination of producers harvesting themselves, hiring custom operators, and possibly the supply co-op itself will have some equipment and staff.

Table 13 shows the financial model for supplying a cellulosic sugar plant with 250,000 tonnes/year of corn stover producing approximately 115,000 tonnes of cellulosic sugar annually with 90,000 tonnes per year of lignin coproduct. The numbers provided are considered to be accurate estimates at the current time and are based on information discussed with industry sources during this study. The capital cost for a plant this size is approximately $70 million. The analysis assumes that half of the capital cost (i.e. $35 million) would be financed over 10 years. The

Table 12. Estimated Equipment and Staff Requirements Based on Harvest Days Available

Variable	Harvest Days		
	30	40	50
Total harvest hours (10/day)	300	400	500
Collection rate required (acres/hour)	947	710	568
Equipment Requirements			
Discbine/stalk chopper with tractor	118	89	71
Rake with tractor	118	89	71
Square baler with tractor	79	59	47
Tractor for bale moving	47	36	28
Estimated new equipment cost ($ million)	$67.0	$50.3	$40.2
Staff Requirements			
Equipment operators	363	272	218
Support	55	41	33
Total Staff	418	313	251

Sources: University of Guelph, Ridgetown Campus calculations using information from Hettenhaus et al. (2009) and www.caseih.ironbuilder.com.
Notes: Support staff include field advisors, management and administration staff. Numbers have been rounded.

ROI calculation is also done over 10 years and is the estimated after tax ROI for the sugar plant assuming it purchases stover from the supply co-op at the cost estimated in Table 11. The ROI is based on the return on private funds with a tax rate of 20%. It assumes that all of the investment is from private funds and is calculated only on the $35 million initial equity investment and not on the total capital costs.

The price used in the analysis that would be received for the sale of cellulosic sugar is based on the World Raw Sugar Price, ICE Contract #11

Table 13. Financial Model for Supply Co-op

General Parameters	Value
Plant biomass capacity (tonnes/year)	250,000
Unit capacity cost ($/tonne/year)	$280.00
Debt to equity ratio	1.00
Interest rate (%)	5.0%
Loan repayment period (years)	10.00
Price of cellulosic sugar ($/tonne)	$400.00
Price of lignin co-products ($/tonne)	$40.00
Cost of corn stover ($/dry tonne)	$129.27
Production and Revenue	**Value**
Cellulosic sugar production (tonnes/year)	115,000
Lignin production (tonnes/year)	90,000
Cellulosic sugar revenue (M $/yr)	$46.00
Lignin revenue (M $/yr)	$3.60
Total revenue (M $/yr)	$49.60
Cost Items	**Value**
Operating costs	
Corn stover cost (M $/yr)	$32.32
Operating costs (M $/yr)	$10.00
Financing costs	
Total capital cost (M $)	$70.00
Initial loan (M $)	$35.00
Initial equity (M $)	$35.00
Interest (M $/yr)	$1.03
Loan repayment (M $/yr)	$3.50
Sub-total financing costs (M $/yr)	$4.53
Net income (M $/yr)	$2.75
Income tax (M $/yr)	$1.25
Return on investment (%)	4.3%

Note: Return on investment is after tax. M – million.

nearby futures price for the first quarter of 2013 as reported by the USDA. It is approximately $0.18/lb or $400/tonne. This is a world benchmark price for sugar acknowledging that it would need to be adjusted to account for local supply/demand conditions, transportation, and quality/purity of the sugar for its intended purpose. It is assumed that the lignin co-product is sold for its energy value ($40/tonne). Total all-in operating costs for the sugar plant are assumed to be $40/tonne of stover processed.

The corn stover is estimated to cost $129.27/tonne delivered to the sugar company. Annual stover procurement and operating costs represent 60% of the total initial capital cost ($70 million). With a projected after tax ROI of 4.3%, reducing this cost is critical. Using the base assumption that 0.88 dry tonnes are harvested per acre, nearly 284,000 acres or 50% of the average corn acreage in the four county region would be required. It was stated previously that many U.S. studies cited in the literature used a 50% participation rate. It is anticipated that in Ontario a 50% participation rate is quite optimistic unless the supply chain is developed through a cooperative model. There are several reasons for this, but one major reason is that Ontario corn yields are usually lower than in the U.S. Midwest (i.e. 35 bushel/acre lower in the 2000's) which means some fields should not have stover removed because this is unsustainable from a conservation standpoint.

When reviewing the base assumptions, there are some key cost drivers that should be further analysed. They include harvest costs (i.e. discbine, raking, baling), nutrient replacement, and transportation distance of 75 km. Also, the ability to harvest from high yielding fields would create efficiencies and drive down the cost per tonne since more stover could be harvested from a smaller acreage.

5.4 Bioprocessing Co-op

A fourth model is the bioprocessing co-op with members consisting of all players in the value chain. By participating in a bioprocessing co-op, corn and sugar producers can be partners and share jointly in the returns and risks of the entire value chain. Corn producers could purchase membership shares (e.g. valued at per acre or tonne of stover to be supplied). For example, if the total initial producer investment is $10 million, then a membership share might be valued at $40/tonne of stover supplied or $45/acre (based on 0.88 dry tonnes/acre). Table 14 shows the financial model for a sugar plant that would use 250,000 tonnes of corn stover to produce approximately 115,000 tonnes of cellulosic sugar annually and 90,000 tonnes of lignin coproduct. It estimates a price for stover that could be paid if a ROI of 15% was desired. The ROI calculation is done over 10 years. The assumptions used in this model are similar to those used in the supply co-op model with the exception being the target ROI. The analysis assumes that half of the capital cost (i.e. $35 million) would be financed over 10 years. Again, the numbers provided are considered to be accurate estimates at the current time.

It is assumed that corn stover producers, custom operators, aggregators, transporters, the cellulosic sugar company and biochemical companies could all potentially provide equity in the project. Based on the information provided in Table 14, the price that could be paid for the corn stover is $110.52/tonne (delivered to the sugar company) in order to achieve a ROI of 15%. Recall that the ROI is based on the return to private funds. The $110.52/tonne cost of corn stover is less than the estimated cost of $129.27/tonne under the supply co-op model. However, corn stover producers can share in this 15% ROI by having membership shares in the co-op and participating in dividends if these are paid out by the co-op. The total value received by the producer for their stover would include the price initially received for the stover plus any potential dividends.

It should be noted for the stover, operating and capital cost assumptions used in Tables 13 and 14, that the annual stover and operating costs combined are approximately 50-60% of the initial capital cost of the cellulosic sugar plant. Table 14 shows the ratio of stover and operating costs ($27.63 million + $10 million) relative to the initial capital costs ($70 million) is approximately 54% in this scenario. In the future it is expected that stover costs will be reduced as the harvest process and equipment become more refined and technology improves. On the revenue side, the new market for stover will help with grain price fluctuations.

Table 14. Financial Model for Bioprocessing Co-op

General Parameters	Value
Plant biomass capacity (tonnes/year)	250,000
Unit capacity cost ($/tonne/year)	$280.00
Debt to equity ratio	1.00
Interest rate (%)	5.0%
Loan repayment period (years)	10.00
Price of cellulosic sugar ($/tonne)	$400.00
Price of lignin coproductsproducts ($/tonne)	$40.00
Cost of corn stover ($/tonne)	$110.52
Production and Revenue	**Value**
Cellulosic sugar production (tonnes/year)	115,000
Lignin coproduct production (tonnes/year)	90,000
Cellulosic sugar revenue ($ million/year)	$46.00
Lingin revenue ($ million/year)	$3.60
Total revenue ($ million/year)	$49.60
Cost Items	**Value**
Operating costs	
Corn stover cost (M $/yr)	$27.63
Operating costs (M $/yr)	$10.00
Financing costs	
Total capital cost (M $)	$70.00
Initial loan (M $)	$35.00
Initial equity (M $)	$35.00
Interest (M $/year)	$1.03
Loan repayment (M $/yr)	$3.50
Sub-total financing costs (M $/yr)	$4.53
Net income (M $/yr)	$7.44
Income tax (M $/yr)	$2.19
Return on investment (%)	15.0%

Note: Return on investment is after tax. M – million.

5.5 Sensitivity Analysis

This section will present a sensitivity analysis based on changing different variables in the supply co-op and bioprocessing co-op models to determine the potential effect on this type of project. Variables analysed include grain corn yield, fertilizer prices and nutrient removal values, transportation distance to end user, sugar yield, sugar price, interest rate, initial equity, inflation, stover removal rates, and moisture content at harvest. Results are presented in Table A1 in Appendix A. It should be noted that for each model (supply co-op and bioprocessing co-op) the stover cost will not always change from the base when a variable is changed. This is because for the supply co-op, the stover cost reflects harvest related costs while the bioprocessing co-op has a target 15% ROI which limits the price it can pay for stover.

Selected results for the impact of changes in grain corn yield, harvest activities, sugar prices and sugar yields are presented as graphs below. It has been stressed previously that it is important to harvest stover at a sustainable rate and this varies from farm to farm. Also, some research has indicated that harvesting stover when grain yields are less than a certain amount (i.e. 150 bushels/acre) should not be undertaken. It is important to recall that the 5 year average in the four county region for 2008 to 2012 was about 163 bushels/acre.

Greater amounts of stover can be harvested from higher yielding fields. For example, the base scenario in the analysis assumed 165 bushels/acre of grain corn, 30% stover removal at 30% moisture resulting in 0.88 dry tonnes/acre harvested. If there was a high production year such as 2012 for much of the region, then more stover could be harvested per acre and potentially reduce the cost. For example, if the average yield increased to 185 bushels/acre, then the stover harvest would be 0.99 dry tonnes/acre and would help decrease the stover cost to $125.59/tonne and improve ROI to 6.4% as shown in Figure 12 below and Table A1 (in Appendix A) under the supply co-op model. Under the bioprocessing co-op model, the cost of stover would remain at $110.52/tonne in order to generate the 15% ROI.

Harvest activities represent a large part of the cost of stover. If there are efficiencies that can be gained or activities removed, these should be explored. For example, Figure 13 shows the base model (using a discbine and rake) compared to the scenarios of not using a discbine and not using either a discbine or a rake. Removing the discbine decreases the cost of stover to $105.75/tonne and improves the ROI to 17.7%. Removing raking further improves these numbers; however, it is unclear how well this would work under Ontario's conditions.

The cost of stover that the bioprocessing co-op can pay is influenced by the price of sugar and by the sugar yield the plant can achieve. With respect to the price of sugar, Figure 14 shows that as the price increases from the base of $400/tonne, the cost of stover the co-op is able to pay increases assuming a target ROI of 15%. For example, if sugar prices increased 20% to $480/tonne, the bioprocessing co-op could potentially afford to pay $147/tonne for the stover and still maintain a 15% ROI.

The sugar yield that the bioprocessing co-op can achieve also has a significant impact on the cost that can be paid for stover while maintaining a target ROI of 15%. This is shown in Figure 15. As sugar production increases, it becomes possible to pay more for stover. In Figure 15, the lower sugar production of 100,000 tonnes/year might be assumed to be from that of early developers of cellulosic sugar conversion technology while the output of 135,000 tonnes/year might be viewed as that from highly engineered companies.

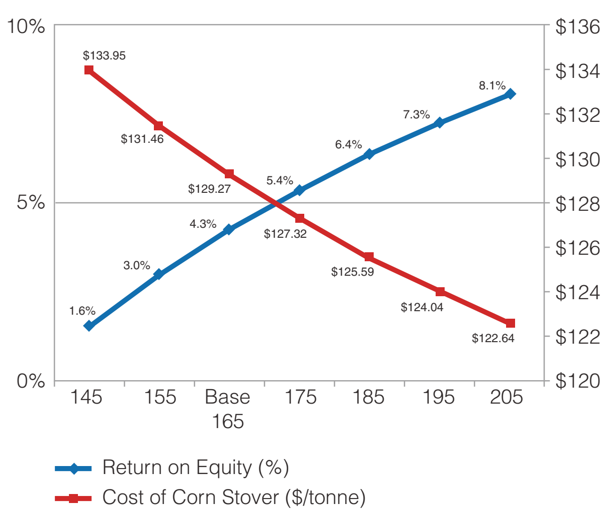


Figure 12. Effect of Grain Corn Yield on ROI and Cost of Stover in a Supply Co-op

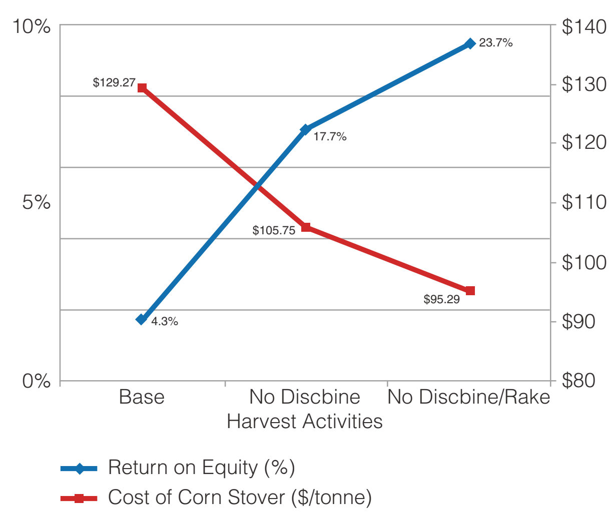


Figure 13. Effect of Harvest Activities on ROI and Cost of Stover in a Supply Co-op

In summary, the sensitivity analysis shows that a large impact on ROI and the cost of corn stover appear to occur with a change in sugar prices or sugar yields. If any producer harvest activities such as using a discbine are unnecessary, then this would contribute to a lower stover cost and higher ROI. Please refer to Appendix A to see sensitivity analysis results for changes in other variables.

Figure 14. Effect of Sugar Price on Cost of Stover in a Bioprocessing Co-op

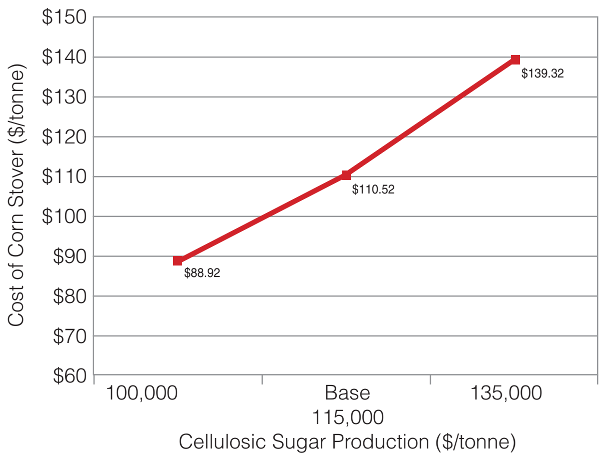


Figure 15. Effect of Sugar Yield on Cost of Stover in a Bioprocessing Co-op

5.6 Central Aggregation Sites

It is suggested that central aggregation sites are needed to ensure constant stover availability for the sugar plant and that there is a need to have the bales out of producer fields prior to spring planting activities. Also, half-load trucking restrictions may exist during certain times of the year restricting movement of bales. These sites would assist in managing inventory, but there would be a tradeoff relating to the ability to truck directly from the producer's field to the sugar plant. Since winter weather in Ontario is unpredictable, there will be times when bales stored on farm will be unaccessible due to snow or mud. It is proposed that there would be one site in each of the four counties and each site would hold approximately four weeks' supply of stover. Combined, the four sites would represent four months of supply for the plant.

The estimated acreage required at each site is 12.5 acres for a total of 50 acres. It is recommended that the total area required should be twice the actual bale storage area in order to allow for access, handling, and sufficient spacing between the bales (Perlack and Turhollow). Therefore, at each site there are 6.25 acres of actual bale storage and 6.25 acres of additional space for access and handling. Using an estimated land value of $10,000/acre, this would require a $500,000 capital investment in the 50 acres of land. Additionally, the estimated investment in materials (excavation/site preparation, limestone/aggregate base, tarp) and labour is $100,000/acre of actual bale storage (i.e. 6.25 acres/site). Based on a ten year amortization and 5% interest rate, the estimated cost is $20/tonne of stover based on stacking bales 6 high with a bale weight of 0.37 tonnes dry matter basis. It is important to note that these costs have not been incorporated in the financial model analysis. Rather, the $8/tonne storage cost estimate previously mentioned has been used. This cost is for end of field storage or storage on-farm with bales tarped.

6.0 – Areas Requiring Further Investigation

Since this is a relatively new concept for Ontario, uncertainties exist at this time. The major concern appears to be the ability to source sufficient quantities of stover each year on an on-going basis at a cost that is economical for both the sugar producer and corn stover producer. There are several key areas to work on and improve in order to reduce uncertainty and lower costs that should be further explored. These are outlined in Appendix B along with potential ways to mitigate the risks. Some of the key areas include:

1. Storage – In terms of storage any significant differences in stover quality of covered bales versus uncovered bales need to be determined as well as the preferred method of storage. As another option, it may be possible to provide a payment to those growers who can provide year-round, accessible storage based on storage requirements established by the co-op; however, this is not part of the analysis.
2. Harvest techniques – What equipment will work best under Ontario conditions? For example, can a stalk shredder attachment on a combine eliminate the need for a discbine and reduce one pass in the field? Two pass systems are being researched in the U.S. Midwest. New high density balers are also becoming available in the market that should lead to reduced harvest and transporation costs.
3. Diversification of biomass sources – A sugar plant requiring 250,000 tonnes of corn stover may need to have alternative sources of biomass (eg. wheat straw, miscanthus, switchgrass and others) to offset issues that may decrease the available corn stover supply in a given year. There is a need to develop a harvest calendar to identify the time of year when other biomass sources are available.
4. Transportation and logistics – The location of the sugar plant will be important as transportation costs are a potentially large cost depending on distance travelled. Also, what is the optimum transportation arrangement regarding size of truck, bale size and weight to reduce transportation costs/tonne? There is work already started on this.
5. Producer manual – This should be developed to outline harvest and storage criteria such as sustainable harvest rates, bale size and acceptable levels of moisture at time of baling.
6. Sugar conversion technology – The potential exists for further improvements in cellulosic sugar yield and quality for its intended purpose in biochemical processing.
7. Additional revenue stream from N, P and K recovery – It may be possible to incorporate technology into the sugar extraction process to allow for the recovery of N, P and K from the stover. This would allow for the recovered nutrients to be converted to a liquid fertilizer which could be resold and provide an additional byproduct revenue stream potentially increasing the ROI. This process would likely have to be on a cost recovery basis and has not been accounted for in the financial analysis in this study.

7.0 Conclusions and Next Steps

The potential exists for Ontario corn producers to harvest corn stover for use in biochemical production. It is important to take into consideration site-specific sustainable harvest rates, but it is estimated that over 500,000 dry tonnes of corn stover are available annually in the four county region of Lambton, Huron, Middlesex and Chatham-Kent.

Some of the main potential benefits resulting from this project could be:

- Agronomic benefits including earlier warming of the ground in the spring enabling earlier seed germination and potentially higher yields. Also, seed emergence may be more uniform if there is less stover to get through.
- New jobs, taxes, revenue streams, and diversification.
- Companies using sugars from corn stover may claim that a portion of their inputs are renewable and potentially have a smaller environmental footprint. In general, bio-based products have lower greenhouse gas emissions (GHG) compared to, for example, similar petro-based processes. This may appeal to certain customers (e.g. chemical industry) and the public may be more receptive to these products. It is impossible to estimate how much GHG's may be reduced because the final end product is unknown.

Four business model options were considered for the cornstalks to biochemical project. The direct sale and request for purchase models were considered to be unfeasible options primarily because the large amount of stover needed for a project such as this is not guaranteed over the long term. It would be onerous for the cellulosic sugar plant to work with the large number of corn stover growers that would be required. The supply co-op model would generate a low ROI for the sugar company which would result in difficulty attracting investment partners and would not allow for producers to participate further along the value chain.

The preferred model is the bioprocessing co-op comprised of corn stover producers, custom operators, aggregators, transporters, cellulosic sugar plant, and biochemical companies where all entities of the value chain could potentially be equity members. The supply chain is de-risked under a co-op model with more equality amongst producer suppliers with respect to delivery dates adjustment, constant supply and re-insurance. Cellulosic sugar is priced based on corn sugar extraction. Both corn and sugar producers face price volatility and a bioprocessing co-op allows for these partners to share this volatility. The financial analysis in this report has used conservative assumptions and a target of 15% ROI. The price a stover producer receives depends on several factors such as sugar prices and sugar yields. Based on the sensitivity analysis, the price that a stover producer might receive could potentially range from $37 to $184/dry tonne. The price would be directly related to the financial performance of the cellulosic sugar producer and any dividend payments. Corn stover producers could potentially retain a larger share of the value chain through a bioprocessing co-op.

This study attempts to establish a relative base price for corn stover. However, individual producer costs will vary significantly due to grain corn yield, equipment used, and transportation distance to the sugar plant. Feedstock supply accounts for the highest proportion of operating costs in the bioprocessing co-op model. On an annual basis, feedstock supply and operating costs are roughly 50-60% of the total initial capital cost for the sugar plant.

Over time, advancements in technologies and yield increases of new corn varieties are likely to occur creating efficiencies and improving costs. Potential opportunities to increase efficiency, reduce corn stover procurement costs, and increase return on investment include:

- the use of new harvesting equipment and logistic processes (eg. high density balers, two pass harvest systems)
- the use of field advisors to ensure sustainable stover harvest on a site specific, field by field basis
- recent Ontario grain corn yield data suggests there are large acreages within the four county region with yields well above 150 bushels/acre where it may be beneficial to remove some of the stover
- potentially incorporating a process to remove the N, P and K from the stover and resell it as a liquid fertilizer to provide additional revenue stream for the value chain co-op
- decreased operating costs and capital costs as current sugar conversion technology improves and new technology emerges

Next steps for a cornstalks to biochemical venture include:

- selecting a technology to convert biomass to sugar
- development of a harvest calendar with alternative feedstocks
- research into supply system efficiency
- research into business innovation to support a biorefinery in Southwestern Ontario
- construction of a demonstration size plant to test the sugar conversion technology
- educating the public and producers about all stages of the project.

A demonstration plant could help address some of these issues and build producer and community interest.

Great potential exists for a sustainable cornstalks to bioprocessing venture in Southwestern Ontario. At the farm level corn producers could benefit by moving up the value chain and addressing some agronomic issues by removing excess stover. The utilization of cellulosic sugar produced from corn stover to produce green chemicals would reduce the environmental footprint through lower greenhouse gas emissions and increased carbon credits in concert with worldwide efforts to develop green chemicals.

References

Agriculture and Agri-Food Canada. *Creating a Co-operative – An Information Guide.* [Online]. Accessed from http://www4.agr.gc.ca/resources/prod/coop/doc/creatcoopguide.pdf

Agriculture and Agri-Food Canada. Date modified: 2013-05-01. *Length of Growing Season in Ontario.* [Online]. Accessed from http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1363033977515&lang=eng.

Agris Co-operative Ltd. (2012) Annual Report.

Al-Kaisi, M. and M. Hanna. (2008). *Managing Residue for a Good Stand.* [Online]. Integrated Crop Management News 04/02/2008. Iowa State University Extension. Accessed February 14, 2013 from http://www.extension.iastate.edu/CropNews/2008/0402AlKaisiHanna.htm

Al-Kaisi, M. and M. Hanna. (2009). *Residue Management and Cultural Practices – Resources Conservation Practices.* [Online]. Iowa State University Extension. Accessed February 14, 2013 from http://www.extension.iastate.edu/Publications/PM1901A.pdf

Anand, M., J.S. Bergtold, D. Archer, P. Duffy, R. Raper. (2010). *Economic and Environmental Impacts of Corn Stover Removal for Biofuel Production: A Farm Level Case Study.* 2010 Southeast Decision Sciences Institute Proceedings February 2010, pp. 90-109.

Archer, David. (2009). *Corn Stover – Cost, Availability, and Sustainability.* [Online]. USDA, ARS. 2009 conference proceedings. Accessed November 2012 from http://renewables.morris.umn.edu/biomass/conferences/2009/Archer-CornStoverCostAvailabilityAndSustainability.pdf

BIO Biotechnology Industry Organization. (2006). *Achieving Sustainable Production of Agricultural Biomass for Biorefinery Feedstock.* Washington, DC.

Blanco-Canqui, H. and R. Lal. (2009). Corn Stover Removal for Expanded Uses Reduces Soil Fertility and Structural Stability. *Soil Science Society of America Journal,* 73(2), 418-426. doi: 10.2136/sssaj2008.0141

Brechbill, S. and W. E. Tyner. (2008). *The Economics of Renewable Energy: Corn Stover and Switchgrass.* Purdue University Extension ID-404-W.

Bryan Boyle & Associates. (2013). *Cornstalks to Biochemicals. Five Producer Focus Groups.* Report prepared for Ontario Federation of Agriculture.

Business Wire. (2002). *Imperial Sugar Company Sells Michigan Sugar Company to Michigan Sugar Beet Growers Inc.* Accessed February 13, 2013 from http://www.thefreelibrary.com/Imperial+Sugar+Company+Sells+Michigan+Sugar+Company+to+Michigan+Sugar...-a082811210

Darr, M. (2011). *Feedstock Logistics Systems for a Large Square Bale Corn Stover Supply Chain.* [Online]. Prepared for USDA Teleseminar on Feedstock Logistics, June 21, 2011. Accessed April 3, 2013 from http://www.ars.usda.gov/SP2UserFiles/Program/213/Teleseminars/Matt%20Darr%20(ISU)%206-21-11.pdf

Dickrell, J. *Cellulosic Ethanol Ramps Up.* [Online]. Agweb.com website article dated May 29, 2012. Accessed February 15, 2013 from http://www.agweb.com/article/cellulosic_ethanol_ramps_up/

Edwards, William. *2012 Iowa Farm Custom Rate Survey.* [Online]. Ag Decision Maker File A3-10. Iowa State University. Accessed February 15, 2013 from http://www.extension.iastate.edu/Publications/FM1698.pdf

Gan, J., J.W.A. Langeveld, C.T. Smith. (2012). *Biomass producer decision making: direct and indirect transfers in different spheres of interaction.* IEA Bioenery Conference 2012, November 13-15, 2012.

Glassner, David, James Hettenhaus, Tom Schechinger. (1999). *Corn Stover Potential: Recasting the Corn Sweetener Industry.* Reprinted from: Perspectives on new crops and new uses. 1999. J. Janick (ed.). ASHS Press, Alexandria, VA.

Gould, K. (2007). *Corn Stover Harvesting.* [Online]. Michigan State University Extension. Accessed February 5, 2013 from http://beef.msu.edu/Resources/Nutrition/CornStoverHarvesting/tabid/595/Default.aspx

Government of Canada. (2011). *Top 50 Non-financial Co-operatives in Canada 2009.* Accessed from http://www4.agr.gc.ca/resources/prod/coop/doc/top_50_2009_eng.pdf

Hess, J.R., K.L. Kenney, C.T. Wright, R. Perlack. (2009). Corn stover availability for biomass conversion: situation analysis. *Cellulose (2009) 16:599-619.* doi: 10.1007/s10570-009-9323-z

Hettenhaus, J., J. Kimble, H. McKay, K. Paustian, A. Swan, D. O'Conner. (2009). Bio-mass *Opportunity for Imperial, NE Region. Corn Stover: What is the Value? Review Draft.* [Online]. Accessed from http://www.biotech-now.org/wp-content/uploads/2010/05/stover-value-review-300410.pdf

Hoorman, J.J. (2009). *Using Cover Crops to Improve Soil and Water Quality.* [Online]. Ohio State University Extension Fact Sheet. Accessed January 23, 2013 at www.mcc.msu.edu

Hoque M., Artz G., Martens B.J., Jarboe, D. (2013). E*ssentials for Producer Participation in Biomass Markets When Choices are Correlated.* [Online]. Southern Agricultural Economics Association 2013 Annual Meeting, February 2-5, 2013, Orlando, Florida. Accessed from http://purl.umn.edu/142747 on January 30, 2013.

Integrated Grain Processors Co-operative Inc. (2012). Offering Statement.

Iowa Corn Growers Association. *Iowa Ethanol Plant numbers.* [Online]. Accessed March 5, 2013 from http://www.iowacorn.org/en/ethanol/iowa_ethanol_plants/

Edwards, W. (2011). *Estimating a Value for Corn Stover.* Iowa State University Ag Decision Maker File A1-70. Revised December 2011. FM-1867.

Iowa State University. (2006). *Iowa farm and rural life poll – 2006 Summary Report.* [Online]. PM 2032 November 2006. Accessed from http://www.soc.iastate.edu/extension/ifrlp/PDF/PM2032.pdf

Jarboe, D. H., B. J. Martens, M. M. Hoque, G. M. Artz. (2012). *Essential Elements for Producer Participation in Biomass Markets.* ASABE Paper No: 12-1337372. St. Joseph, Mich.: ASABE

Karlen, D.L. and S.J. Birrell. Undated. *Stover Harvest – Safe and Sustainable With Good Resource Management Practices.* [Online]. Accessed January 10, 2013 from http://www.poet.com/pr/data-shows-responsible-biomass-harvesting-is-part-of-good-soil-managem

Khanna, M., and Huang, H. (2010). *The Breakeven Costs of Producing Alternative Feedstocks for Cellulosic Biofuels.* [Online].

Energy Biosciences Institute, University of Illnois, Urbana-Champaign, http://miscanthus.ebi.berkeley.edu/biofuel/documents/Feedstock Production Cost.pdf

Kladivko, Eileen. (2011). *Cover Crops for Modern Cropping Systems.* [Online]. Purdue University. Accessed from http://www3.ag.purdue.edu/agry/extension/Documents/CoverCropsOverview.pdf

Kludze, H., B. Deen, A. Weersink, R. van Acker, K. Janovicek, A. De Laporte. (2010). *Assessment of the Availability of Agricultural Biomass for Heat and Energy Production in Ontario.* Report prepared for Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA)

Lane, Jim. (2013). *The cellulosic biofuels tipping point.* [Online]. biofuelsdigest.com January 8, 2013. Accessed from http://www.biofuelsdigest.com/bdigest/2013/01/08/the-cellulosic-biofuels-tipping-point/

Lee, D., V.N. Owens, A. Bee, P. Jeranyana. (2007). *Composition of Herbaceous Biomass Feedstocks.* [Online]. North Central Sun Grant Center, South Dakota State University. Accessed from http://ncsungrant.sdstate.org/uploads/publications/SGINC1-07.pdf

Li, X., E. Mupondwa, S. Panigrahi, L. Tabil, S. Sokhansanj, M. Stumborg. (2012). A review of agricultural crop residue supply in Canada for cellulosic ethanol production. *Renewable and Sustainable Energy Reviews 16 (2012) 2954-*2965. doi: 10.1016/j.rser.2012.02.013

Marketing Horizons, Inc. (2001). *Bioethanol Fuel Production Concept Study – Topline Report.* [Online]. NREL, U.S. Department of Energy. NREL/SR-510-31247.

McDonald, I. (2010). *Agricultural Residues – crops, harvesting logistics, soil sustainability.* [Online]. Presentation dated February 9, 2010. Accessed February 13, 2013 from http://www.ofa.on.ca/uploads/userfiles/files/ian%20 mcdonald.pdf

Milhollin, R., Hoehne, J., Horner, J., Weber, S., George, C. (2011). *Feasibility of Corn Stover in Missouri.* [Online]. Accessed October 16, 2012 from http://agebb.missouri.edu/commag/resources/CornStoverReport.pdf

Moorey, R.V., N. Kaliyan, D.G. Tiffany, D.R. Schmidt. (2010). A Corn Stover Supply Logistics System. A*pplied Engineering in Agriculture Vol. 26(3):* 455-461. American Society of Agricultural and Biological Engineers ISSN 0883-8542.

Nafziger, E.D. Undated. *Residue Management and Nitrogen Response in Continuous Corn.* [Online]. FREC Project # 335. Accessed February 12, 2013 from http://www.ifca.com/media/files/residue_management_and_nitrogen_response_in_continuous_corn.pdf

Nafziger, E.D. Undated. *Residue Management and Nitrogen Response in Continuous Corn.* [Online]. FREC Project #335. Accessed February 15, 2013 from http://www.ifca.com/media/files/residue_management_and_nitrogen_response_in_continuous_corn.pdf

Ontario Ministry of Agriculture and Food. Date modified: February 15, 2013. *Climate Zones and Planting Dates for Vegetables in Ontario.* [Online]. Accessed from http://www.omafra.gov.on.ca/english/crops/facts/climzoneveg.htm

Ontario Ministry of Agriculture and Food. (2012). *NMAN Software.* http://www.omafra.gov.on.ca/english/nm/nman/nman3.htm

Ontario Ministry of Agriculture, Food and Rural Affairs. (2002). *How to Form a Co-operative.* [Online]. Factsheet. Agdex # 836, Order # 02-019. Accessed November 7, 2012 from http://www.omafra.gov.on.ca/english/busdev/facts/02-019.htm

Ontario Ministry of Agriculture, Food and Rural Affairs and Agriculture and Agri-Food Canada. 2009. *Canada Land Inventory Agricultural Capability.* [Online]. Accessed from http://www.omafra.gov.on.ca/english/landuse/gis/soil_data/40I13.pdf

Ontario Co-op. (2012). *Co-op Comparisons.* [Online]. Accessed from http://www.ontario.coop/cms/documents/1/Co-op_Biz_Comparisons_and_legal_combined_April2012.pdf

Oo, A., C. Lalonde. (2012). *Biomass Crop Residues Availability for Bioprocessing in Ontario.* Western Sarnia-Lambton Research Park. Report prepared for Ontario Federation of Agriculture.

Oo, A., K. Albion, S. Abercrombie, C. Lalonde. (2012). *Alternative Technologies to Transform Biomass into Energy.* Western Sarnia-Lambton Research Park. Report prepared for Ontario Federation of Agriculture.

Osborne, S., R. Anderson, R. Lehman, J. Lundgren, W. Riedell, S. Papiernik. *Soil and Crop Management Systems for Improved Natural Resource Quality and Efficiency (421397).* [Online]. USDA, Agricultural Research Service Project Number 5447-12620-003-00. Accessed February 13, 2013 from http://ncccwa.ars.usda.gov/research/projects/projects.htm?ACCN_NO=421397

Perlack, R.D., A.F. Turhollow. (2002). *Assessment of Options for the Collection, Handling, and Transport of Corn Stover.* [Online]. Oak Ridge National Laboratory. ORNL/TM-2002/44. Accessed February 6, 2013 from http://www.ornl.gov/~webworks/cppr/y2001/rpt/113127.pdf

Perrin, R., J. Sesmero, K. Wamisho, D. Bacha. (2012). Biomass supply schedules for Great Plains delivery points. *Biomass and Bioenergy 37 (2012) 213-220.* doi: 10.1016/j.biombioe.2011.12.010

Petrolia, D.R. (2008). The economics of harvesting and transporting corn stover for conversion to fuel ethanol: A case study for Minnesota. *Biomass and Bioenergy 32(2008) 603-612.* doi: 10.1016/j.biombioe.2007.12.012

POET-DSM Advanced Biofuels. *Project LIBERTY Biomass Producer Handbook.* [Online]. Accessed January 1, 2013 from http://www.projectliberty.com/handbook/

Rankin, M. Undated. *Putting a Value on Corn Stover.* [Online]. University of Wisconsin Extension. Accessed November 11, 2012 from http://www.uwex.edu/ces/crops/CornStoverValue.htm

Schechinger, T.M. and J. Hettenhaus. (1999). Corn Stover Harvest. *Grower, Custom Operator, and Processor Issues and Answers.* [Online]. Accessed from http://infohouse.p2ric.org/ref/40/39095.pdf

Sesmero, Juan P. (2011). *Sustainability of Corn Stover Harvest for Biomass.* Selected paper prepared for presentation at the Agricultural & Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pennsylvania, July 24-26, 2011.

Sokhansanj, S. and A.F. Turhollow. 2002. Baseline Cost for Corn Stover Collection. *Applied Engineering in Agriculture.* Vol. 18(5): 525-530.

Statistics Canada. *2011 Census of Agriculture.* [Online]. Accessed from http://www.statcan.gc.ca/ca-ra2011/index-eng.htm

Stewart, Greg. (2011). *Crop Residue Value. OMAFRA Crop Talk.* [Online]. Accessed October 16, 2012 from http://www.omafra.gov.on.ca/english/crops/field/news/croptalk/2011/ct-0611a8.htm

Thompson, J., W.E. Tyner. (2011). *Corn Stover for Bioenergy Production: Cost Estimates and Farmer Supply Response.* Purdue Extension RE-3-W, Rev 9/11.

Tyndall, J. (2007). *Corn Stover as a Biofuel Feedstock in Iowa: Characterizing Farmer Interest to Supply.* [Online]. Presentation slides at 2007 Biobased Industry Outlook Conference. Accessed from http://www.bioeconomy conference.org/07%20Sessions/approved07 sessions/Tyndall,%20John.pdf

USDA, NASS. *2011 State Agriculture Overview Iowa.* [Online]. Accessed Jan 13, 2013 from http://www.nass.usda.gov/Statistics_by_State/Ag_Overview/AgOverview_IA.pdf

Van Eerd, L., C. Trueman, S. Loewen, R. Vyn. (2011). *Impact of Cover Crops on Processing Tomato: Yield, Quality, Pest Pressure, Soil Health, and Economics. 2011 Research Report.* [Online]. Accessed January 23, 2013 from http://www.mccc.msu.edu/states/Ontario/2011_OTRI_ResearchReport.pdf.

Verhallen, A., A. Hayes, T. Taylor. (2001). *Cover Crops: Adaptation and Use of Cover Crops.* [Online]. Ontario Ministry of Agriculture, Food and Rural Affairs. Accessed from http://www.omafra.gov.on.ca/english/crops/facts/cover_crops01/cover.htm. Last reviewed May 22, 2013.

US Department of Energy. (2011). *US Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry.* R.D. Perlack and B.J. Stokes (Leads), ORNL/TM-2011/224. Oak Ridge National Laboratory, Oak Ridge, TN. 227p.

Wilhelm, W.W., J.M.F. Johnson, D.L. Karlen, D.T. Lightle. *Corn Stover to Sustain Soil Organic Carbon Further Constrains Biomass Supply. Agronomy Journal 99:1665-1667 (2007).* doi: 10.2134/agronj2007.0150

Wortmann, C.S., R.N. Klein, C.A. Shapiro. (2012). *Harvesting Crop Residues.* [Online]. NebGuide G1846 Revised August 2012. University of Nebraska Lincoln. Accessed February 13, 2013 from http://www.necga.org/content/Harvesting%20Crop%20Residues.pdf

Appendix A – Sensitivity Analysis for Supply Co-op and Bioprocessing Co-op Financial Models

Table A1. Sensitivity Analysis for Supply Co-op and Bioprocessing Co-op Financial Models

Variable	Base	Change from Base	Supply Co-op: Effect on ROI (ROI fluctuates)	Supply Co-op: Effect on Stover Cost (ROI fluctuates)	Bioprocessing Co-op: Effect on ROI (constant ROI=15%)	Bioprocessing Co-op: Effect on Stover Cost (constant ROI=15%)
Sugar price	$400/tonne	+$80/tonne	25.3%	129.27	n.a.	147.32
		+$160/tonne	46.4%	129.27	n.a.	184.12
		-$80/tonne	-16.7%	129.27	n.a.	73.72
		-$160/tonne	-37.8%	129.27	n.a.	36.92
Sugar yield	115,000 tonnes	+20,000 tonnes	20.8%	129.27	n.a.	139.32
		-15,000 tonnes	-8.0%	129.27	n.a.	88.92
Interest rate	5%	6%	3.8%	129.27	n.a.	109.63
		7%	3.3%	129.27	n.a.	108.72
Initial equity	50%	60%	5.6%	129.27	n.a.	109.60
		40%	2.3%	129.27	n.a.	111.44
Target ROI	15%	20%	n.a.	129.27	20%	101.77
		25%	n.a.	129.27	25%	93.02
		10%	n.a.	129.27	10%	119.27
Inflation	0%	1%	-0.2%	135.24	n.a.	108.67
		2%	-4.9%	141.54	n.a.	106.72
Transportation	75 km	50 km	6.2%	125.84	n.a.	110.52
		100 km	2.3%	132.69	n.a.	110.52
		150 km	-1.6%	139.53	n.a.	110.52
Nutrient replacement	N25%;P40%; K90%	100%	-3.0%	142.08	n.a.	110.52
Fertilizer prices	Urea $658; MAP $765; Potash $685	+20%	2.8%	131.93	n.a.	110.52
		+40%	1.3%	134.59	n.a.	110.52
		-20%	5.8%	126.60	n.a.	110.52
		-40%	7.3%	123.94	n.a.	110.52
Grain corn yield	165 bu/acre	155 bu/acre	3.0%	131.46	n.a.	110.52
		145 bu/acre	1.6%	133.95	n.a.	110.52
		175 bu/acre	5.4%	127.32	n.a.	110.52
		185 bu/acre	6.4%	125.59	n.a.	110.52
		195 bu/acre	7.3%	124.04	n.a.	110.52
		205 bu/acre	8.1%	122.64	n.a.	110.52
Stover removal rate	30%	40%	9.1%	120.77	n.a.	110.52
		50%	12.1%	115.68	n.a.	110.52
Moisture at harvest	30%	25%	7.7%	123.28	n.a.	110.52
		20%	10.7%	118.04	n.a.	110.52

Note: Base model stover costs: $129.27/tonne (supply co-op); $110.52/tonne (bioprocessing co-op);
ROI – return on investment; n.a. – not applicable

Appendix B - Potential Project Risks and Steps to Mitigate Risks

Table B1. Potential Project Risks and Steps to Mitigate Risks

Risks to Stover Producer		Steps to De-Risk
Number of producers who will sell their stover		• Need "champions" who will help secure producer involvement
Amount of stover produced	• Weather affects production • Planting intentions may change	• Purchase from another farmer if necessary
Weather	• Wet harvest • Potential compaction	• Moisture up to 30% before penalty; spring baling? • Reduce field passes
Storage	• Rain may cause spoilage • Storing at end of field – accessibility; next crop • Harvest moisture impact on bale quality • Fire	• Tarp/cover bales on well drained site • Producer must ensure accessible year-round location on farm or central storage • Insurance on stored bales
Nutrient removal	• Cost to replace nutrients	• Transparent pricing formula
Impact of stover removal long-term	• How much is sustainable? • How to increase amount? • Effect on future yields? • Soil compaction, erosion, organic matter	• Site specific removal rates – field advisors; monitoring over time • Cover crops, reduced till options? • Research needed
Timing of harvest	• Too busy to harvest stover • Short harvest window	• Hire custom op
Equipment needed	• Large capital expense • Are there enough custom operators?	• Hire custom op • Equipment pool?
Broken bales in field	• Affects next crop if not removed or spread out	• Whoever does baling must remove/spread
1 buyer of stover		• Buyer is co-op, producer is member
Transportation	• Sufficient trucking available?	• Have exclusive arrangement with 1 company
Delayed pick-up	• Quality of bales/loss over time	• Lottery system for delivery • Premiums for later pick-up dates
When does ownership change?	• Timing of payment	• Payment schedule • Price FOB processor
Risks to Custom Operators/Supply Co-op		
Weather	• Wet weather at harvest • Who decides when to harvest?	• Moisture up to 30% • Field advisor & producer discuss
Equipment	• Large capital expenses	• Contract with producers or co-op • Spread expenses over other crops
Labour	• Short harvest period	• Spread labour over other crops • Competitive wages • Training
Risks to Sugar Company		
Supply of stover	• Long term supply commitment • Weather limits stover production • Does weather/timing of harvest affect sugar content? • What % moisture is allowable? • Quality, shrinkage • Other competitors	• Contract with co-op or partner in co-op • Use other products i.e. wheat straw • Data from samples, demo plant needed • Penalty assessment for moisture/ash • Source 5-10% more • Secure supply of stover/inputs
Technology	• What will results be at full scale?	• Demonstration plant results will be helpful
Bale shape	• Acceptable size • Misshapen bales due to shrink, storage	• Establish parameters with supplier(s)

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Storage yard	• Fire • Liability • Health and safety of employees due to handling bales, mold	• Insurance • Provide adequate and ongoing training, safety equipment
Market for sugar		• Multiple buyers • Partner in co-op
Market for lignin		• Multiple buyers
Waste management	• Twine, broken bales • Nutrients	• Sell nutrients to farmers
Price of stover	• Variable costs	• Base price to farmer + % of bioprocessing returns
Risks for Biochemical Processor		
Logistics of supply chain	• Ability to harvest and transport stover	• Partner with value chain members
Supply of sugar	• Quantity • Quality • Price	• Partner with sugar producer in co-op • Establish quality parameters • Multiple sources
Market for biochemicals		• Multiple buyers • End user partner in co-op

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