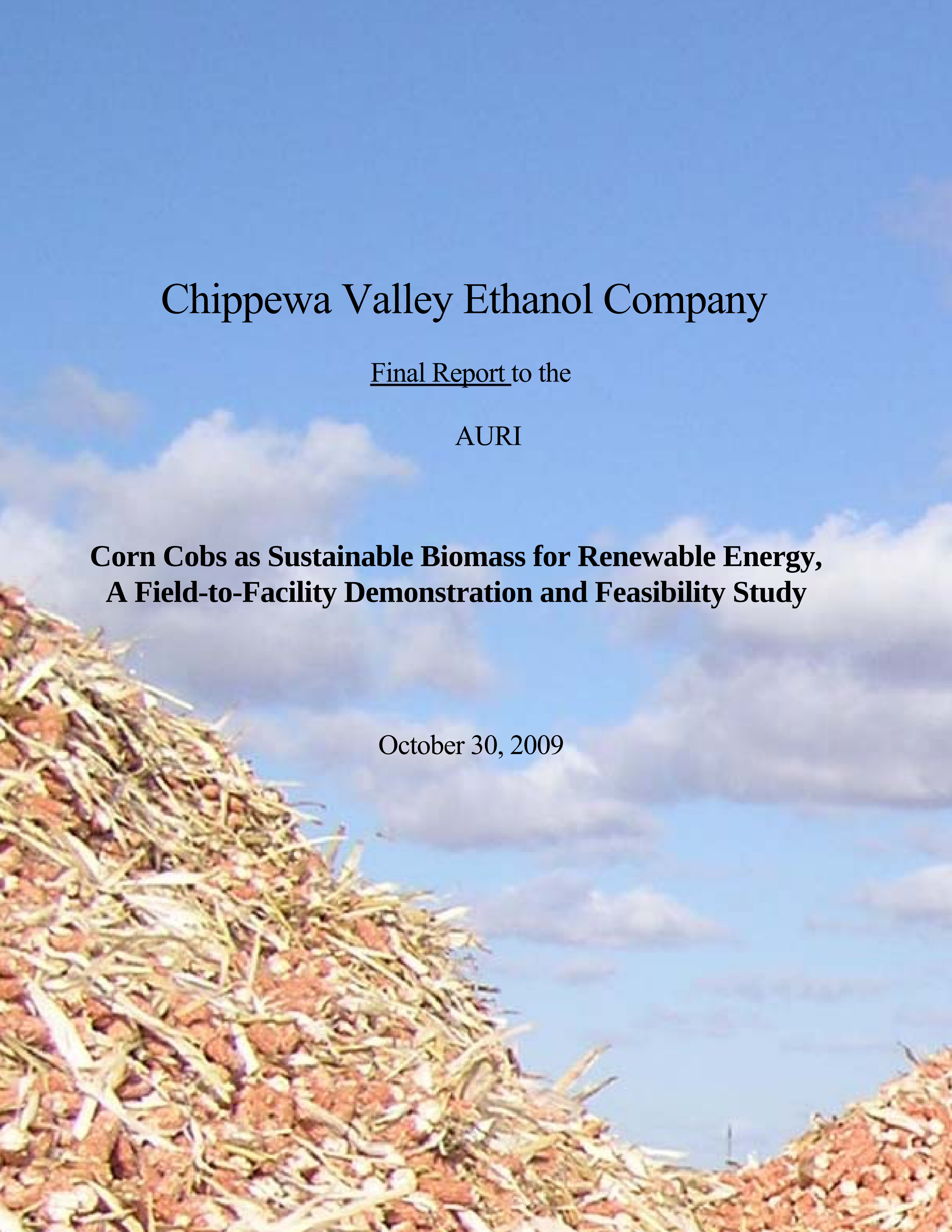


Chippewa Valley Ethanol Company

Final Report to the

AURI

Corn Cobs as Sustainable Biomass for Renewable Energy, A Field-to-Facility Demonstration and Feasibility Study

October 30, 2009

Contents

Acknowledgements

This project was made possible, in part, through grants provided by;

- The Minnesota Office of Energy Security
- Minnesota Corn Research and Promotion Council
- Agricultural Utilization Research Institute/Center for Producer Owned Energy
- The University of Minnesota Initiative for Renewable Energy and the Environment

Executive Summary

Chippewa Valley Ethanol Company (CVEC) partnered with the University of Minnesota - West Central Research and Outreach Center (WCROC) to evaluate the financial and mechanical feasibility of harvesting corn cobs and delivering them to the CVEC biomass gasifier. The project was made possible by grants from the Minnesota Office of Energy Security, the Minnesota Corn Research and Promotion Council, the Agricultural Utilization Research Institute/Center for Producer Owned Energy and the University of Minnesota Initiative for Renewable Energy and the Environment (IREE).

Cob collection equipment was leased from two equipment companies, Vermeer and Ceres, to provide some comparison of collection technologies. CVEC farmer owners participated in the cob harvest project and roughly 1,600 dry ton of cobs were collected from 3,172 acres. Cobs were typically stored at the end of the field and were transported to a staging area near CVEC over the winter. Corn cobs are ground (chipped) at the staging area and combined with wood chips for receiving and feed into the CVEC gasifier. Such blending promotes cob flow through the biomass receiving screen and dilutes the impact of cobs in the gasifier. The cob / wood blend has performed extremely well in the gasifier and 500 ton of cobs have been gasified to date. Pure cob feed behavior and performance in the gasifier is planned for the near future.

Three (3) field demonstration days were conducted during the cob harvest. The demonstration days allowed area farmers, news people, Politician's and Minnesota State staff to watch both the Vermeer and Ceres cob harvesters in action. The corn cob collection project has been documented in an outreach video and brochure. The outreach video includes footage of the cob harvesting and interviews with farmers, University staff and Politicians who explain the benefits and need to use corn cobs as sustainable biomass for renewable energy. The video also includes footage of cob grinding and receiving into the biomass gasifier system at CVEC.

The WCROC study finds that corn cobs can be harvested, stored and transported under real world production conditions and cobs may be a viable and economic feedstock for biomass energy systems. And that additional research and farmer initiative is required to refine cob harvest efficiency and more accurately define harvesting costs.

CVEC is in process of deploying 7 Vermeer cob harvesters this 2009 harvest season with the hope of collecting corn cobs from 12,000 to 14,000 acres. The cost to harvest and deliver corn cobs to CVEC is being estimated at $33 per acre for the 2009 harvest season.

The corn cob field-to-facility project is a success in that it has demonstrated and documented the viability of corn cobs as a sustainable source of biomass for renewable energy. The corn cob demonstration has also served as a spring board toward the continuing effort to utilize corn cobs as an energy resource.

Corn Cob Field-to-Facility Project Fact Sheet

- Chippewa Valley Ethanol Company (CVEC) is located in Benson, MN (population 3,300) and is owned by 980 farmers and local community members. The ethanol plant produces 48 million gallons annually, employs 53 people and will spend $66 million dollars locally in 2010. Ethanol production and transportation and the creation of a biomass supply chain may stimulate an additional 50 jobs. CVEC owns and operates a commercial size biomass gasifier as a means to displace natural gas and reduce their carbon footprint and corn cobs are considered a primary biomass feed stock.

- The project cob harvest was managed by CVEC, conducted on CVEC member acres and evaluated by the University of Minnesota - West Central Research and Outreach Center.

- Corn cobs are desirable as a sustainable biomass for energy feedstock because……

    - Cobs represent a small, 12% portion of corn stover remaining on the field and cob removal has negligible impact on organic carbon depletion from the soil
    - Cobs are primarily carbon and have limited nutrient value to the soil
    - Cob harvest can be done simultaneously during cob harvest without adding significant delays
    - Cobs store and shed moisture better than baled and stacked material
    - Cobs are slightly more dense then the average bailed material
    - Cobs are collected at the combine discharge which avoids the inclusion of rocks and dirt in the biomass supply
    - Cobs are easy to gasify because they contain low levels of nitrogen, silica and other minerals
    - Whole and ground cobs have excellent flow properties and can be handled with conventional conveyors

- The Vermeer CCX cob harvester was deployed on 1,804 acres and the Ceres Cob Residue System was deployed on 1,368 acres for a total of 3,172 acres

- Typical cob yield is around 1,000 dry pounds per acre.

- Three (3) field demonstration days were conducted in which area farmers, news people, Politicians and Minnesota State staff were able to watch both the Vermeer and Ceres cob harvesters in action.

- An outreach video and brochure have been produced to document the cob harvest project and explain the value of cobs as a renewable energy resource.

- Given that prototype cob harvester equipment was used for the project, final commercial purchase price of the equipment was not available. Consequently, CVEC used projected costs by the manufacturers to establish equipment costs. The best available estimate of the cost of cob harvester equipment, fuel, time and delivery of corn cobs to CVEC was approximately $33 per acre, or $66 per ton, for the 2009 cob harvest.

- Both the Vermeer and Ceres cob harvest equipment were prototypes so equipment comparisons and harvest efficiencies are preliminary. The following table shows the results of this study.

Cob Harvest System Comparison

Harvest System	Acres Harvested	Corn Grain Yield / Ac (bu)	Separator Ac / Hr	Combine Ac / Hr	Fuel Consumed Gal / Ac*
Vermeer Cob Caddy	1804	157.3	7.48	6.20	3.90
Ceres Cob System	1368	165.1	7.78	3.23	3.84

*Includes fuel consumed for grain harvest.

- Considering the unusually wet conditions presented in the Fall of 2008, outside cob storage should be a viable option. Cob pile moisture varied seasonally from 36% to 42% with the wettest occurring at harvest and in the spring. However, further evaluation of cob storage options should be conducted in order to minimize storage losses, decrease risk and lower costs.

- Additional research also is required to better determine the economic opportunity for corn farmers, equipment suppliers and ethanol facilities. In particular, the economic impact of reducing GHG/carbon dioxide emissions by using corn cobs to reduce the use of natural gas or coal for process heating needs has not been determined. Additional evaluation is also needed to better establish net change in GHG emissions. However, the $66 per ton price estimated for delivered cobs at the ethanol plant is feasible. Particularly if cob collection equipment and cob storage is optimized, and if costs benefits of net reduced carbon dioxide emissions are significant.

- For the scope of this project, the corn cob field-to-facility project successfully documented the technical and logistical viability of corn cobs as a sustainable source of biomass heating fuel for production of ethanol. Given this outcome, further evaluation of the net economic and environmental benefits resulting from use of corn cobs as heating fuel for renewable energy is merited.

Corn Cobs for Ethanol Production Process Heating:
A feasibility report of collection, storage and use of corn cobs as a renewable ethanol production process heating fuel

Michael Reese, Renewable Energy Director
University of Minnesota- West Central Research and Outreach Center

Objective

The objectives of this feasibility study are:

- Determine Cob Yield
- Determine Cost Per Ton of Cobs
- Evaluate and Compare Cob Harvest Systems
- Evaluate Storability and Deliverability of Cobs

Introduction

There are several bottlenecks to the successful adoption of biomass energy systems. One of the most profound challenges is the efficient and effective supply of biomass feedstock to the facility. In general, agricultural biomass is a bulky and inconsistent material varying in energy density, moisture, composition, and cleanliness. The development of efficient and financially viable feedstock supply chains is critical to the successful operation and future development of biomass energy systems.

There is an abundant supply of corn stover for biomass feedstock across the Corn Belt including the State of Minnesota. Unfortunately, the field-to-facility supply of corn stover presents some of the most difficult feedstock challenges within the emerging industry. Corn stover is a bulky, stringy, dusty, and inconsistent material. Therefore, corn stover is difficult to harvest, transport, store, and process in an efficient and financially viable manner. Agricultural feedstocks such as small grain straw, native grasses, and soybean residue present similar challenges and no clear-cut choice.

The selective harvest of corn cobs may provide a viable near-term option for these reasons:

- Ability to segregate while combining does not significantly slow down corn harvest.
- Ability to be stored in bulk piles reduces storage costs.
- Higher density reduces transportation costs.
- Lower ash content reduces fertility losses to the soil.
- Low functionality in soil carbon cycles and soil erosion mitigates sustainability concerns.
- Compatibility with material handling systems designed for wood biomass reduces the complexity and added investment needed by end-users.
- Harvest process limits the introduction of dirt, rocks, and other debris.
- Cobs are generally a more consistent feedstock than corn stover.
- Composition may provide a better gas and emissions profile than corn stover.

Over the past year, Chippewa Valley Ethanol Company, in collaboration with other stakeholders including the Minnesota Corn Research & Promotion Council, Agriculture Utilization Research Institute, and the University of Minnesota West Central Research and Outreach Center demonstrated and evaluated the field-to-facility supply of corn cobs to biomass energy systems.

Chippewa Valley Ethanol Company (CVEC), owned by over 980 farmers and local community members, operates a 46 million gallon per year ethanol plant located in Benson, MN. In an effort to become more sustainable and significantly reduce dependency on natural gas, CVEC has installed a biomass gasification system which will provide thermal energy to the corn ethanol facility. Corn cobs have been identified as a possible primary feedstock for this gasification system. If cobs were harvested from every acre of corn required for the ethanol plant, the cobs would provide as much as 50% of the thermal energy requirement. Therefore, corn cob harvest provides a desirable synergy for a typical corn ethanol plant.

Corn cobs have several desirable characteristics when compared with other agricultural biomass feedstocks. Cobs make up approximately 12% of the corn stover remaining in the field after corn harvest. Therefore, removal of the cobs alone will reduce concerns of organic carbon depletion from the soil and would keep valuable nutrients within the soil. Corn cobs are primarily carbon and have limited nutrient value containing approximately 0.90% nitrogen, 0.05% phosphorus, and 0.80% potassium. The harvest of cobs can occur simultaneously during corn harvest without adding significant delays. Once harvested the cobs may store and shed moisture better than baled and stacked material. When comparing full truck loads, corn cobs are slightly denser than the average bale, and therefore, more weight can be delivered per load. One of the most significant advantages is that no or limited processing is required once the cobs enter the biomass energy intake system. Cobs are essentially a large and very consistent pellet. In contrast, bales must be processed by grinding and the resulting material can still be very inconsistent. The bale grinding process produces significant amounts of dust, uses considerable energy, and is subject to foreign material such as rocks. Since the cobs are captured in the combine with only limited contact to the ground during storage, the possibility of foreign material entering the system and causing damage is significantly reduced. Since corn cobs are low in nutrients, they may perhaps provide a cleaner synthesis gas stream and emissions profile within a gasification system especially when compared to corn stover gasification issues such as high levels of HCl, NOx, and silica.

A demonstration and evaluation of corn cob harvest occurred in the Fall of 2008. Approximately 3,200 acres of corn cobs where harvested utilizing two different cob harvest systems. The resulting corn cobs where stored and then delivered to the Chippewa Valley Ethanol Company. At CVEC, the corn cobs have begun to be utilized in the biomass gasification system. The West Central Research and Outreach Center has been participating in the acquisition and evaluation of data including the collection of cob samples, cob moisture, cob yield, harvest and transport costs, harvest capacity, energy consumption, and storability.

On February 6, 2008, CVEC farmer members were invited to a meeting in which the demonstration and evaluation was detailed. Following the meeting, 17 members submitted a total of 19,000 corn acres for participation in the demonstration. The members were also asked to indicate whether or not they would be willing to modify their combines for use in the demonstration.

The large scale cob demonstration and evaluation took place in the Fall of 2008. In addition to the large scale evaluation, three field days where held at participating farms and the two different types of the corn harvesters where demonstrated. Two eight-row combines with stalk chopping heads were utilized with each combine utilizing a unique cob harvest system. The Vermeer CCX was a pull behind cob harvester that contained its own power source. The only modifications were a hitch to the back of the combine and a remote control cord running to the combine cab. The second cob harvest system evaluated was a Ceres Cob System. The Ceres unit consisted of a separator and blower mounted to the back and a storage tank mounted to the top of the combine. The combines and cob harvest systems where used to harvest approximately 3,200 acres of corn and corn cobs. Participating farmers paid CVEC a standard fee for the harvest of corn and chopping of the stalk residue. CVEC then paid the custom harvester, compensated the farmers for the corn cobs, and took responsibility for the corn cobs out of the combine. The farmers agreed to store the cobs at the end of the field or an alternate location until needed by CVEC. The farmers were responsible for the transport of the corn grain from the combine. The end result was that farmers had their grain harvested and the value received from the cobs defrayed approximately one-half of the corn grain harvest expense. The three field days were open to the public and were well attended by farmers, policy makers, energy consumers, and other citizens. Tours of the biomass gasification systems at CVEC and the University of Minnesota, Morris are on-going.

Materials and Methods

Evaluation and Comparison of Cob Harvest Systems
Vermeer CCX (Picture 1-2) and the Ceres Cob Residue System (Picture 3-4) were individually evaluated for harvest capacity as the separator and combine hours were noted for each field. Total fuel consumption for the combine, cob harvest system (Vermeer), and the tender wagons were recorded for each field. Following the evaluation, time and fuel consumption were averaged on a per acre basis.

Determination of Cob Yield
Cob yield is a major factor in determining feasibility. Initially, three methods were to be used to determine cob yield. However, due to poor weather conditions and the need to expedite harvest for the participating farmers, hand harvest evaluation was the sole method used for determination of yield. Ears of corn were harvested from three 100 foot sections of each test field. The cobs were shucked, shelled, and weighed. Cob sample dry matters were determined by standard protocol utilizing sample drying ovens at the WCROC. The grain and cob dry matters were determined from the following equation:

Percent Dry Matter = (Dry weight / Wet weight) *100

Grain and cob yields were determined by first determining the area represented by 100 feet in 22 inch or 30 inch rows and then developing a respective factor (238.1 for 22 inch and 175.4 for 30 inch rows).

Grain Yield per Acre (bu) = ((Total sample weight * % Grain) * (238.1 or 175.44)) / 56 lbs / bu

Cob Yield per Acre (lbs) = (Total sample weight * % Cob) * (238.1 or 175.44)

Determination of Cob Harvest Costs
Obtaining reliable data for determining the cost of cobs proved difficult due to several factors. Since the cob harvest systems were prototypes, the cost of the cob harvest equipment was not readily available. The differences in grain versus cob harvest costs were difficult to separate. The poor fall harvest conditions resulted in an expedited harvest and the exact total tonnage of cobs harvested was not determined. Since two cob harvest systems were compared, corresponding data for grain harvest alone was not available.

Evaluation of the Storability and Deliverability of Cobs
Every two weeks, the cob storage pile conditions and temperatures were assessed. Samples were obtained for percent moisture determination. Temperature and moisture levels were recorded.

Results and Implications

Evaluation and Comparison of Cob Harvest Systems
The cob harvest systems were used across a total of 3,172 acres with the Vermeer CCX and the Ceres Cob System covering 1,804 and 1,368 acres respectively (Table 1). Both systems logged similar amounts of acres per hour for the combine separators and consumed between 3.90 and 3.84 gallons of diesel fuel per hour. The Vermeer CCX logged more acres per hour of combine operation. Since only two units were compared, there was no statistical analysis performed. For grain harvest alone, combines can generally cover between 10 to 15 acres per hour and will consume between 1.3 and 2 gallons of fuel per acre. Therefore, cob harvest roughly doubled the combine time and fuel required.

Table 1. Cob Harvest System Comparison

Harvest System	Acres Harvested	Corn Grain Yield / Ac (bu)	Separator Ac / Hr	Combine Ac / Hr	Fuel Consumed Gal / Ac*
Vermeer Cob Caddy	1804	157.3	7.48	6.20	3.90
Ceres Cob System	1368	165.1	7.78	3.23	3.84

*Includes fuel consumed for grain harvest.

Determination of Cob Yield

Twenty-eight fields were sampled across a sixty-mile region. The results indicate an average grain yield of 192 bushels of per acre (adjusted to 15.5% moisture), an average cob yield of 996 lbs per acre (on a dry matter basis), and average respective grain and cob harvest moisture levels of 23.6 and 39.5 %. The results on a field by field basis are shown in Table 4. Based on the respective corn grain and cob yields, a predictive model was developed for producers (Table 2). The model requires additional data for refinement but does give a general indication of expected cob yield based on corn grain yield. Halvorson and Johnson (2009) compared corn grain and cob yield on irrigated fields in the Central Plains. The researchers determined that there was a linear effect between cob and grain yields and suggested that cob yield increases 95.5 kg / ha-1 for every 1 Mg / ha-1 of grain yield.[1]

Corn varieties were also noted in the evaluation. Anecdotal information prior to harvest suggested that there were considerable differences between corn varieties as to the yield, moisture level, and other cob characteristics. The raw data along with numerical differences are listed in Table 4. Two Pioneer corn varieties planted at the West Central Research and Outreach Center were further evaluated and an ANOVA statistical analysis was performed. The results indicate there was a significant cob yield difference between the varieties (Table 3). Since there were only two varieties no meaningful information can be derived other that there are significant differences between varieties and additional research is needed. A larger cob varietal evaluation is planned for Fall 2009.

Table 2. Predicted Cob Yield at Various Grain Harvest Levels

	Expected Corn Grain Yield (Bu / Ac)								
	100	120	140	160	180	200	220	240	260
Projected Cob Yield Dry Matter Basis (Lbs / Ac)	690	760	820	880	950	1020	1090	1140	1210
Projected Cob Yield 40% Moisture (Lbs / Ac)	1167	1267	1367	1467	1583	1700	1817	1900	2017

$R^2 = 0.243$

Table 3. WCROC Cob Variety Yield Evaluation

Field	Variety	Corn Grain Yield / Ac (bu)	Corn Grain % Moisture	Cob Dry Matter Yield / Ac (lb)	Cob % Moisture
WCROC 1	38H66	233.9	24.7	1098.7 a	43.3
WCROC 2	37Y14	189.8	27.8	811.8 b	52.7

P value < 0.10

Table 4. On-Farm Cob Hand Harvest Results

Field/ Grower	Field #	Variety	Grain Yield (bu/Ac)	Cob Yield (Tons/Ac)	Cob Yield (Lbs/Ac)	% of Yield that is Grain	% of Yield that is Cob	Cob % Moist.	Grain % Moist.
Fynboh	1	Pioneer 37Y13 / mix	125.53	0.3646	729.2000	85.833	14.167	42.2	24.4
North Farm	3	Dklb 5020	175.34	0.3723	744.6000	88.550	11.450	48.5	27.8
North Farm	2	DKlb 5020	197.70	0.3729	745.8000	89.117	10.883	53.2	31.2
Wentzel FF	4	N46-D9	166.05	0.3742	748.4000	88.083	11.917	46.0	25.3
WCROC	2	Pioneer 37Y14	189.90	0.4048	809.6000	87.633	12.367	52.7	27.8
Fynboh	3	Pioneer 37Y13 / mix	142.56	0.4164	832.8000	84.900	15.100	48.6	27.6
Wentzel FF	10	N40t	201.63	0.4342	868.4000	88.033	11.967	51.2	29.4
T. Wentzel	1	N40t/Dklb 46-60	176.46	0.4365	873.0000	87.867	12.133	40.6	24.4
B. Erdman	1	NA	174.76	0.4467	893.4000	88.250	11.750	34.5	19.9
Fosso	1	Dekalb	230.94	0.4675	935.0000	89.850	10.150	40.4	22.3
Wentzel FF	11	N40t/Dklb 46-60	197.28	0.4707	941.4000	87.033	12.967	52.7	33.3
Fosso	2	Dekalb 3427	205.88	0.4716	943.2000	87.900	12.100	44.2	21.8
T. Wentzel	3	N40t	206.36	0.4752	950.4000	87.133	12.867	53.0	31.0
Arnold	8	Pioneer 37Y14	217.94	0.5043	1008.6000	88.450	11.550	40.0	20.6
Ascheman	1	Dekalb 5019	188.39	0.5102	1020.4000	89.333	12.333	33.4	20.4
K. Lundberg	1	NA	193.44	0.5140	1028.0000	87.767	12.233	35.9	21.3
Wentzel FF	7	8881 RR	168.81	0.5188	1037.6000	86.817	13.183	30.9	19.9
Strand	2	3724 & 3824, Grst 89Z07	193.58	0.5338	1067.6000	85.650	14.350	33.1	21.2
Wentzel FF	9	N40t	188.01	0.5446	1089.2000	87.400	12.600	32.8	22.3
WCROC	1	Pioneer 38H66	233.92	0.5494	1098.8000	88.317	11.683	43.3	24.7
Wentzel FF	13	N33J	180.03	0.5513	1102.6000	86.250	13.750	35.6	21.1
P. Frank	1	NA	210.34	0.5672	1134.4000	89.800	11.867	29.8	19.8
Arnold	3	Dekalb 46-60	201.54	0.5810	1162.0000	87.367	12.633	34.4	23.5
Arnold	5	Dekalb 46-60	197.55	0.5847	1169.4000	87.653	12.367	27.8	19.6
Wentzel FF	6	N40t/88H48	226.75	0.5854	1170.8000	87.867	12.133	41.3	25.4
Arnold	6	Wensman 7267	182.97	0.5971	1194.2000	86.983	13.017	22.9	17.3
Strand	1	Dklb 4327, Crpln Gen	192.55	0.6427	1285.4000	87.867	12.133	30.4	19.5
K. Evenson	1	NA	210.43	0.6515	1303.0000	86.967	13.033	27.7	17.7
Average			**192.02**	**0.4980**	**995.9714**	**87.667**	**12.453**	**39.5**	**23.6**

*Grain yield is calculated on a 15.5% moisture basis, 56 lbs./bu.

*Cob yield is calcualted on a 0% moisture basis

*Three one hundred foot random sections from each field were hand harvested to determine grain and cob yield and moisture content.

Determination of Cob Harvest Costs

The cost per ton of cobs was difficult to determine in this evaluation due to several factors. More research is required to further refine the cost of cob harvest and utilization. The cob harvestor data compared to normal combine harvest time and fuel consumption seems to indicate that the harvest cost will double with cob harvest. If the assumption is made that cob harvest takes an extra 2 gallons of fuel per acre and twice as much time in harvesting, a producer can expect an additional cost of $20 to 30 per acre. This would suggest a cost per ton for cob harvest to be approximately $50 per dry ton (based on a yield of 1000 lbs per acre DM basis). Transportation and storage losses also need to be added to the cost. Based on a fifteen mile average haul and average load of 20 wet tons, the transportation costs are approximately $3 per ton or $5 per dry ton. An initial evaluation indicates an average loss of cob dry matter at approximately 1 % per month. This loss does not consider the reduction of energy value of the remaining material. If cobs are stored for an average of 6 months, than a 6 % decrease in dry matter is anticipated. This should result in a 6% increase in the amount of biomass required and a similar increase in the cost per dry ton of biomass consumed by the biomass energy system.

Evaluation of the Storability and Deliverability of Cobs

Every two weeks, the cob storage pile conditions were assessed. Moisture and temperature levels were determined. Results are shown in Graphs 1-3. On average the piles maintained a very good condition from time of harvest through the end of July. The Fall 2008 harvest season was extremely wet which resulted in corn and cob moisture levels to be very high, averaging 23.6% and 39.5 % respectively. Cobs ranged up to over 53% moisture. Once the cobs were place into piles there was a concern that some may begin to heat and spontaneously combust. Moisture and temperature data was collected every 2 weeks from the fall harvest to August. However, initially two piles began to approach temperatures over 150 degree F and were mechanically ventilated. The problem piles were monitored on a daily basis until ventilation stabilized the temperature. As noted in Graphs 1 through 3, moisture and temperature throughout the winter moderated and then began to increase slightly in the wetter spring months. The storage pile conditions than moderated again in the summer months. Throughout this time frame, the piles most susceptible to deteriation were delivered to the CVEC facility for processing and later utilization within the gasification system. Considering the unusually wet conditions presented in the Fall of 2008, outside cob storage should be a viable option. However, further evaluation of cob storage options should be conducted in order to minimize storage losses, decrease risk, and lower costs. Ventilation appears to be a good option.

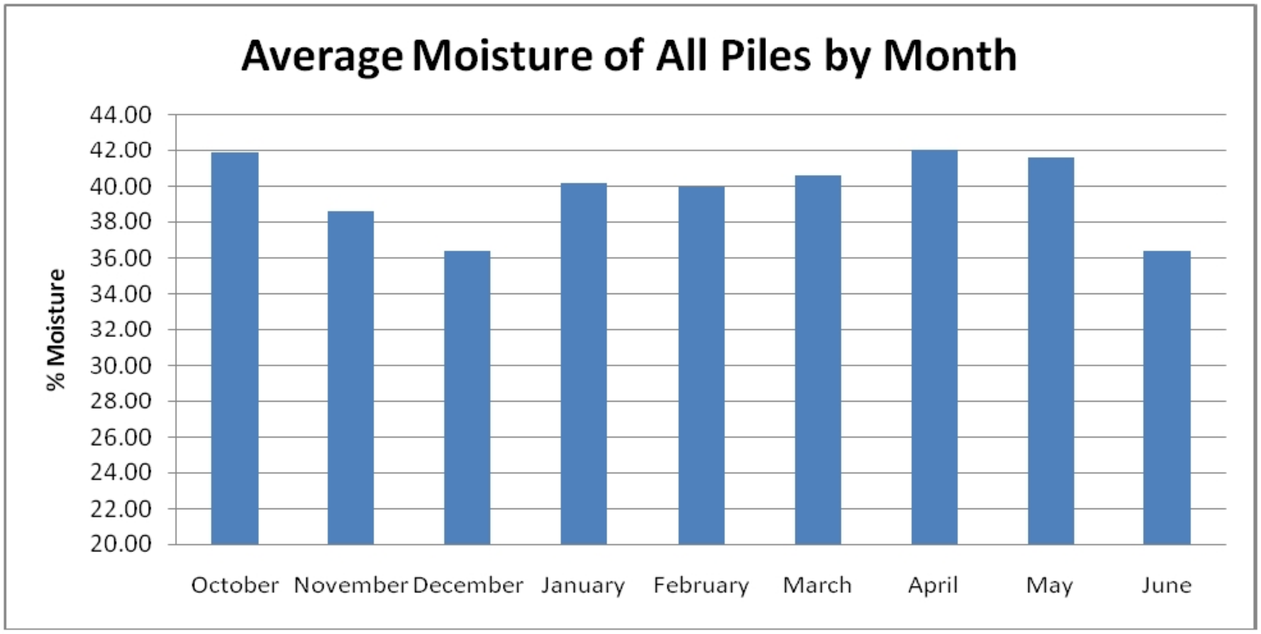
In conclusion, corn cobs can be harvested, stored, and transported under real world production conditions. The results indicate that cobs may be a viable and economical feedstock for biomass energy systems. Additional research and farmer initiative is required to refine the efficient field-to-facility supply of corn cobs to biomass energy systems.

The University of Minnesota West Central Research and Outreach Center wishes to thank and acknowledge the leadership of the Chippewa Valley Ethanol Company and its producer members. This project was funded by the Minnesota Department of Commerce, Minnesota Corn Research and Promotion Council, Agriculture Utilization Research Institute, the University of Minnesota Initiative for Renewable Energy and the Environment, and the Chippewa Valley Ethanol Company.

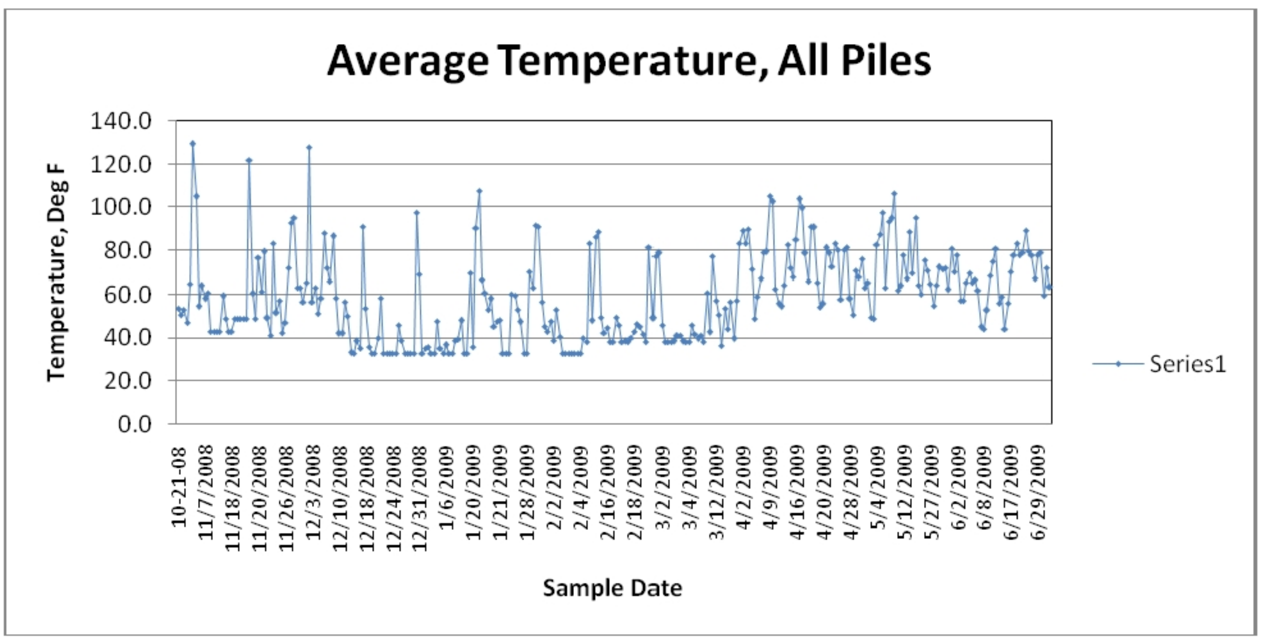
Literature Cited

1. Halvorson, Ardell D. and Johnson, M.F., *Corn Cob Characteristics in Irrigated Central Great Plains Studies*, Agronomy Journal 101: 390-399 (2009), 2009 American Society of Agronomy, 677 S. Segoe Rd., Madison, WI 53711 USA

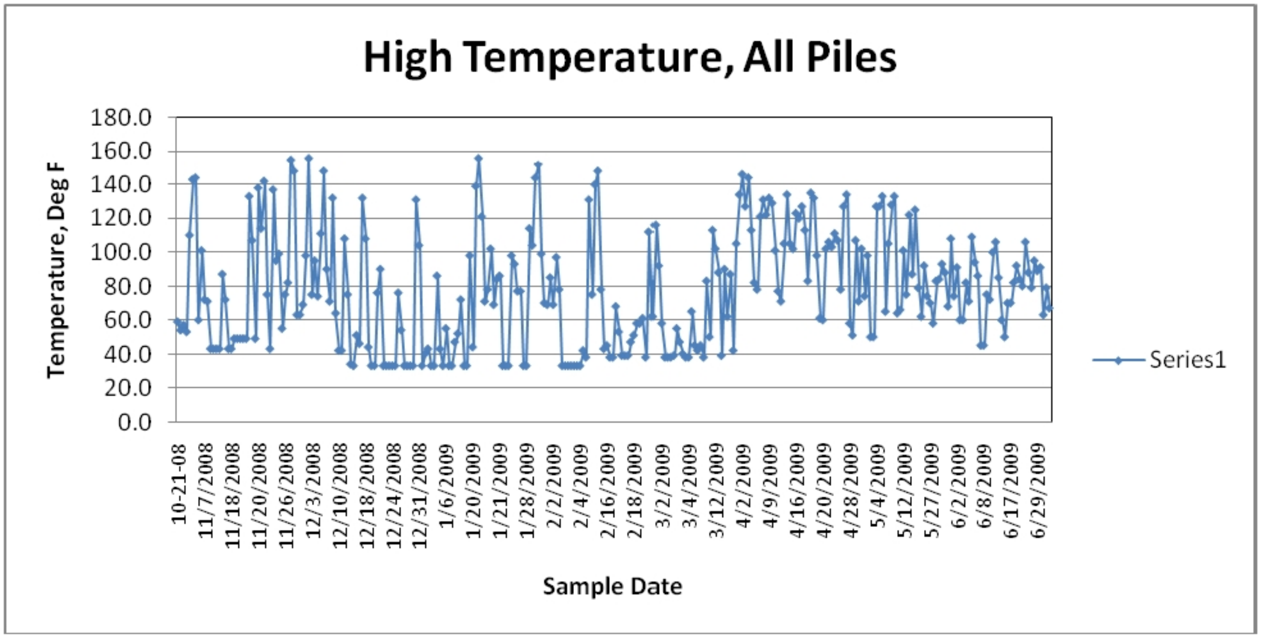
Graph 1. Cob Pile Moisture from Harvest to Utilization



Graph 2. Cob Pile Average Temperatures from Harvest to Uitlization



Graph 3. Cob Pile High Temperatures from Harvest to Utilization



Picture 1. Vermeer Cob Harvest System in field operation.

Picture 2. Vermeer CCX unloading cobs.

Picture 3. Ceres Cob Harvest System mounted on the top and back of the combine.

Picture 4. Ceres Cob System unloading cobs on the go into the Ceres Top Tank.

Corn Cob Harvest Photos


AURI


7010
Vermeer


TOPTANK