THE ECONOMICS OF CORN COB CELLULOSIC ETHANOL FOR NORTHWEST IOWA

by

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ABSTRACT

To meet the demand of the 2007 Energy Bill will require a new approach to ethanol production in the United States. The question persists: how can the ethanol industry in the United States produce 21 billion gallons of ethanol from cellulosic sources? This challenge will require changes in the facilities currently manufacturing ethanol, the collection and storage methods to which the Midwestern farmer is accustomed, and a drastic change in farm production practices. Several different methods of cellulosic ethanol production are being examined. One such method is to change the focus from starch based ethanol to ethanol produced by harvest, collection, and manufacture from corn cobs. Research has included surveys, development of economic models, and focus group meetings to determine the feasibility of corn cobs as a viable raw material source for cellulosic ethanol. Findings indicate that: corn cob collection is feasible for the Midwestern farmer. According to the economic models presented in this thesis, Midwestern farmers can benefit economically from the collection of corn cobs. Further, the collection of corn cobs allows for current ethanol plants to be upgraded with new technology without major change in the manufacturing processes. The focus of this research was to determine which method of corn cob collection was preferable for Midwestern corn producers.

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CHAPTER 1: INTRODUCTION

1.1 Ethanol

Ethanol has been used as a fuel source since the 1800s when German inventor Nikolaus Otto built the first four stroke internal combustion engine (Energy kids, 2007). The need for non-petroleum fuel during World War I provided demand that caused ethanol production to increase in the early part of the 20th century. However, after World War II, the price of oil dropped dramatically resulting in the cessation of ethanol production (Energy kids, 2007). Today, the ethanol industry is a rapid growth segment of the energy complex due to the increase in the price of crude oil and government incentives for renewable fuels. Early growth in the ethanol industry in the U.S. can be attributed to the United States' policy to reduce dependence on foreign oil, the demand for petroleum based products at reasonable prices, and the need to replace MTB's with a cleaner oxygenate.

The two largest ethanol producers in the United States currently make up 27% of ethanol production: POET based in Sioux Falls, South Dakota and Archer Daniels Midland, headquartered in Decatur, Illinois. Total production of these two companies with planned expansions is 1.539 billion gallons for POET and 1.620 billion gallons for ADM. (Renewable Fuels Association, 2007). These two companies lead the ethanol market in research and development.

The question of where the additional feedstock needed to make ethanol will come from to meet increasing demands is a pressing question for United States ethanol producers. This focus is most intense in the Midwestern states and for the farmers who produce in these areas. According to Ethanol Producer magazine, the top five ethanol producing states in 2007 were, in order, Iowa, Nebraska, Illinois, Minnesota, and South Dakota (2007). [1] Midwestern farmers looking for sales outlets for their corn were the first to champion the building of ethanol plants. Initially, the capital needed for the plants was raised by local farmers. But larger companies stepped in as capital needs soared and the need for managerial expertise increased. Companies such as POET and ADM funded and constructed a large number of ethanol facilities in the United States and have purchased other plants resulting in a consolidation of the industry.

Due to rapid growth of the U.S. ethanol industry, some major producers are looking for alternative feedstocks for use in ethanol production. This is due to government incentives for cellulosic feedstock including subsidies for the blending of ethanol, as well as increased demand from the public for alternative fuels and government mandates. One of these companies, POET, has partnered with the Department of Energy to develop a method to meet the renewable fuels standards set forth by the Energy Bill of 2007. POET is investing in a $200 million expansion to its Emmetsburg, Iowa production facility to be the first commercial cellulosic ethanol producer to use corn cobs along with corn in the manufacturing of ethanol.

[1] Top ethanol states vary little in six months. (2007) *Ethanol producer magazine*. Retrieved Sep. 1, 2008, from http://www.ethanolproducer.com/article.jsp?article_id=2818.

CHAPTER 2: CURRENT ETHANOL PRODUCTION

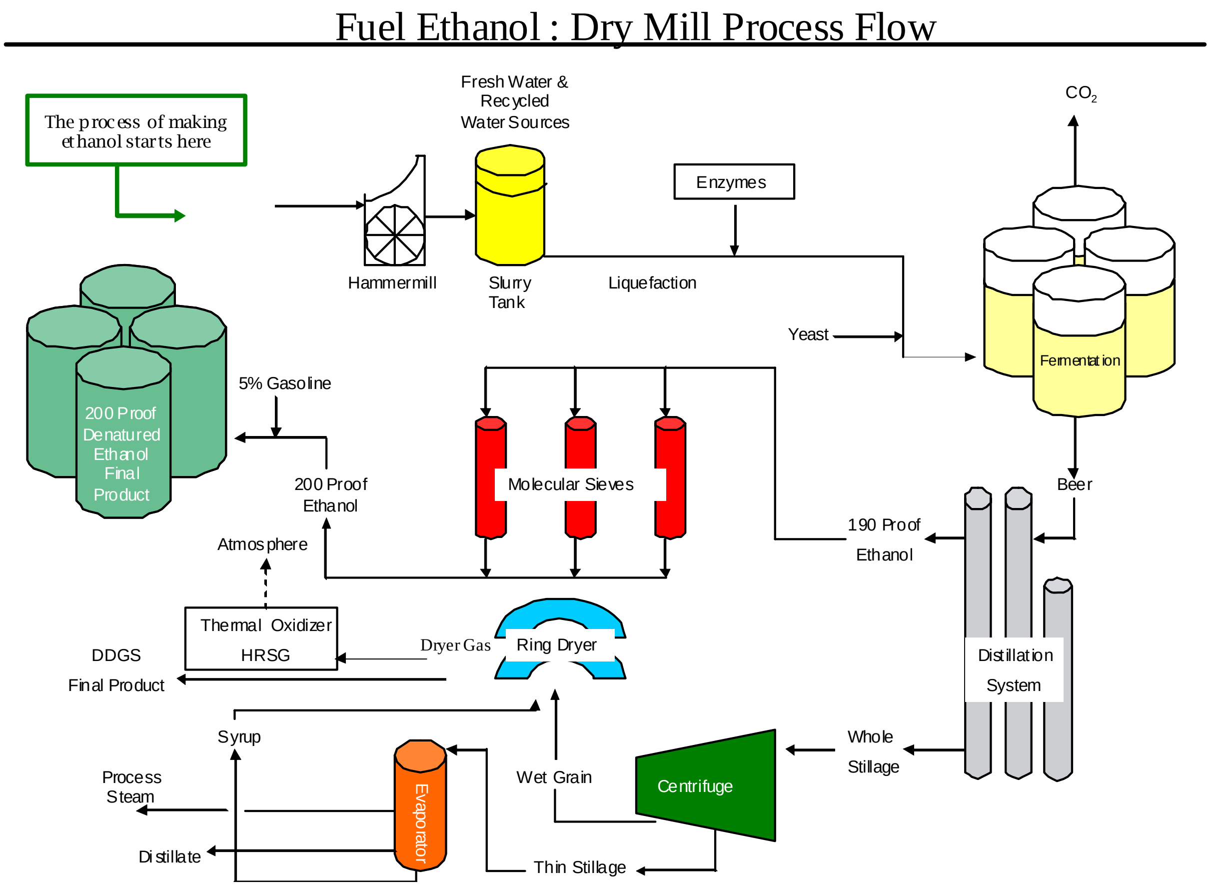
2.1 Ethanol production cycle

There are two methods currently used to produce ethanol from corn in the United States: dry milling and wet milling. Dry mill ethanol production is more energy efficient and less expensive than the wet mill process (Johnson, 2007). In a typical dry mill ethanol plant, the process starts with corn being delivered via truck or rail by local producers. The corn is stored at the facility until it is needed for the processing. Corn is then transferred to a hammer mill where it is ground to a flour consistency (Figure 2.1). The corn flour is conveyed into a slurry tank along with water and yeast. The pH of the slurry is controlled by the use of sulfuric acid. The pH level is important to the overall process because the optimal performance of yeast is obtained with a pH level between 4 and 4.5. The mash mixture is then transferred into a fermentation tank along with enzymes and yeast. The enzymes break corn starch down into the simple sugars that the yeast ferments into carbon dioxide and ethanol. After 50 to 65 hours of fermentation, the yeast produces a beer that contains 16% to 20% alcohol by volume (POET, 2007).

The beer is sent to the distillation process to separate the alcohol from the liquid. A series of distillation columns boil the alcohol out of the water. This process continues until it yields 190 proof (or 95%) alcohol. The 190 proof alcohol is then passed through a series of molecular sieves. These sieves contain very small zeolite balls that are the size of a BB. The sieve beads absorb the remaining water leaving 200 proof alcohol.

The slurry mixture contains solids called solubles. This mixture is sent through a series of centrifuges that spin out these solubles. The solids are put through evaporators to remove more water and thicken the solubles to a syrup. The plant can either sell the solids as wet cake (65% moisture) to local cattle markets or send the solids through a series of dryers that dry the material to 10% moisture. Solubles with this lower moisture percentage are called Dried Distillers Grains with Solubles (DDGS). DDGS are then loaded on railcars or trucks and sent to different feed markets.

Figure 2.1: Fuel Ethanol – Dry Mill Process Flow



(POET, 2007)

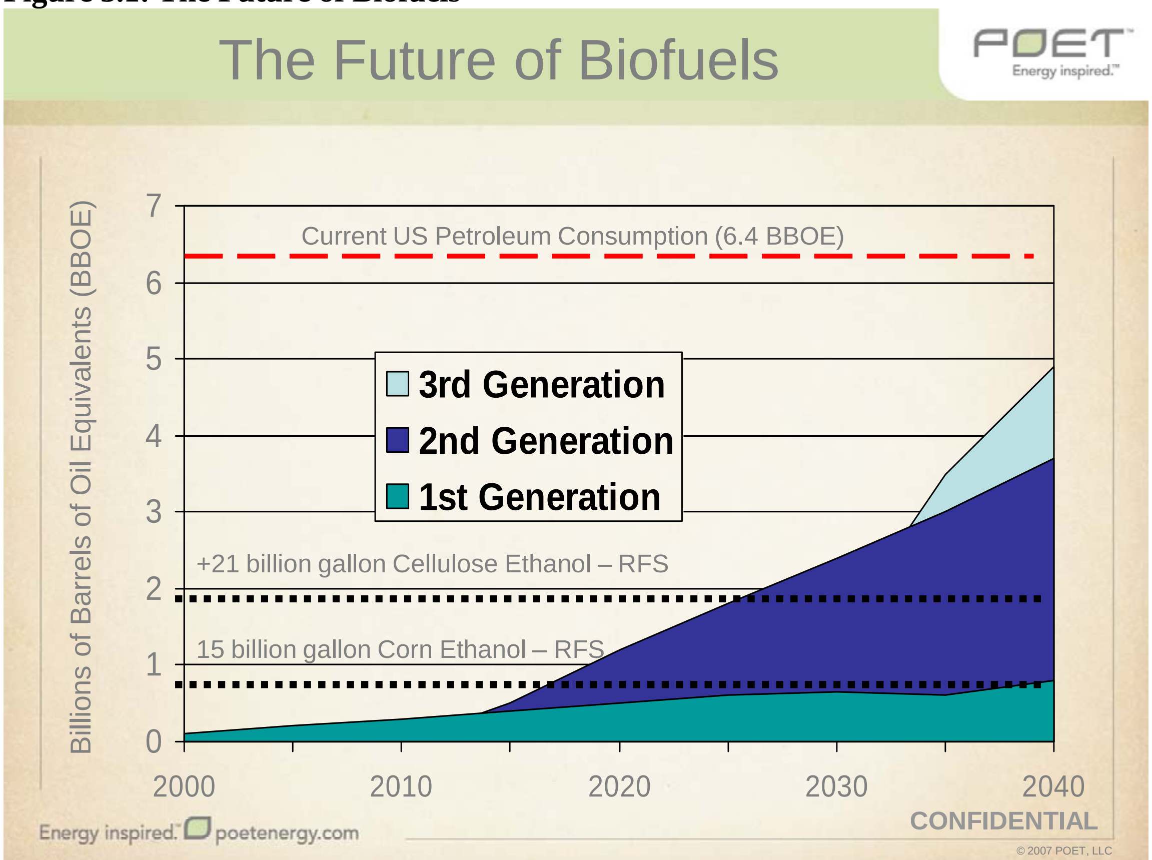
CHAPTER 3: CELLULOSIC ETHANOL

The energy bill signed by President Bush on December 19, 2007 set new standards for renewable energies, and more importantly for this discussion, ethanol (see Figure 3.3). The bill has many provisions, but one important provision is the limit on starch based ethanol production of 15 billion gallons. The balance of the mandate, 21 billion gallons of ethanol, must come from cellulosic sources. The total ethanol mandate for 2022 is five times more than current ethanol plant production capacity (Renewable Fuels Standard, 2007).

Cellulosic ethanol is made from the cellulose contained in plant fibers. Ethanol is currently produced from soft starches, such as corn. As of January 2009, 170 ethanol plants were in operation producing 10.57 billion gallons of ethanol annually. There were 24 plants under construction that will produce an additional 2.0 billion gallons of ethanol (RFA). Production of soft starch ethanol will be capped at 15 billion gallons in 2015 as specified in the 2007 energy bill (Figure 3.2) (POET, 2007). More than 4.2 billion bushels of corn are used for ethanol production. Unless the United States can increase corn production by 2015, the other uses of corn, such as for human, export and animal consumption could suffer from the mandate. The Energy Bill takes this into consideration with its cap of 15 billion gallons. Currently, there are no commercial cellulosic ethanol plants in operation in the United States.

Cellulosic ethanol technology is rapidly developing, but is still expensive compared to corn starch ethanol technology. The Department of Energy (DOE) estimates that cellulosic ethanol production to be $2.20/gal, almost double the cost for corn based ethanol. The majority of this cost is for the enzymes that are used to break the starch or cellulosic material down into simple sugars that the yeast can digest. The enzyme cost is projected to decrease in the next five years. This will make cellulosic ethanol less costly to produce, perhaps making the cost similar to the corn based ethanol. The DOE is investing millions of dollars in the research and improvement of cellulosic based ethanol technology.

Figure 3.1: The Future of Biofuels

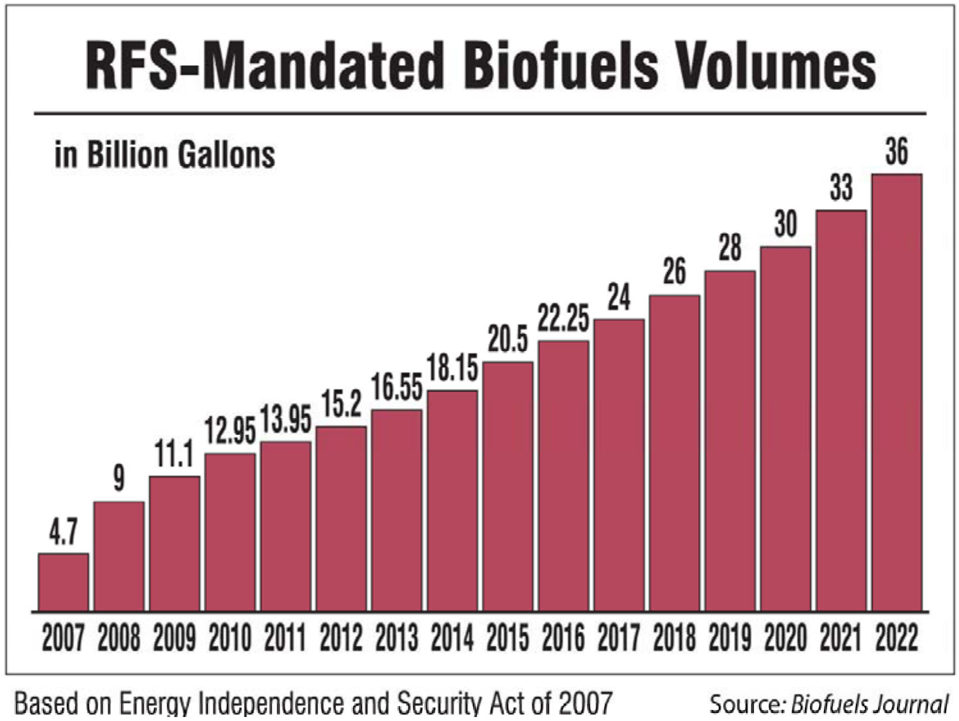


Note: First generation is corn based ethanol

Second generation is cellulose ethanol

Third generation is advanced biofuels, such as green gasoline, diesel and jet fuels made from algae.

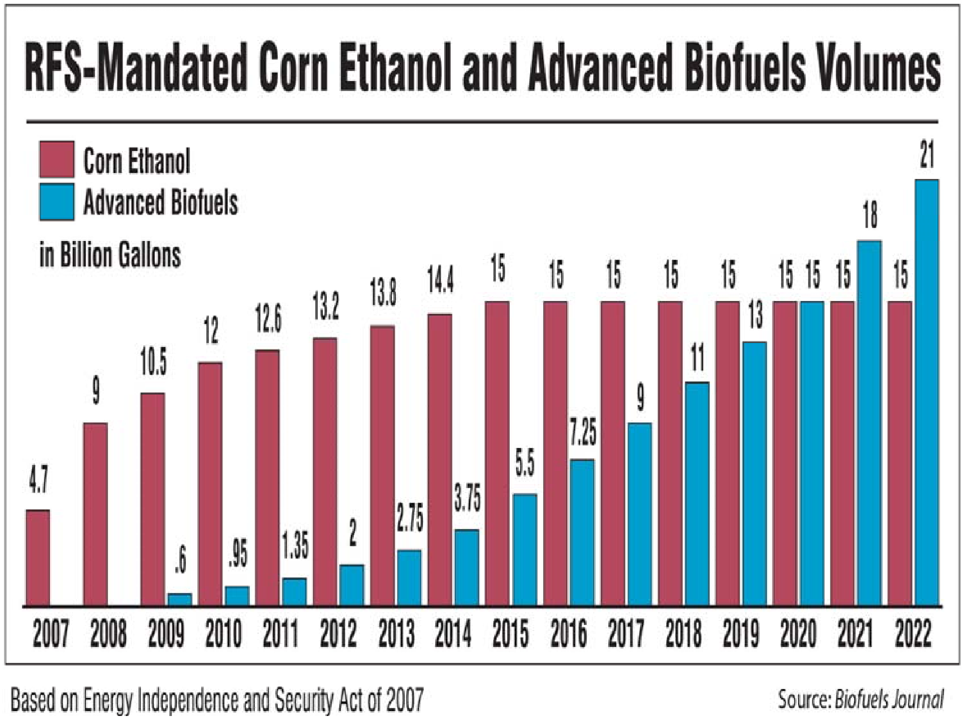
Figure 3.2: RFS-Mandated Biofuels Volumes



(Mayberry, 2008)

Note: This table is a visual reference to the 2007 Energy Bill, which mandates 36 billion gallons of biofuels by the year 2022.

Figure 3.3: RFS-Mandated Corn Ethanol and Advanced Biofuels Volumes



Note: This table is a visual reference of the volumes of biofuels mandated by the Renewable Fuels Standard.

(Mayberry, 2007)

3.1 Benefits of using cobs

There are numerous advantages to using corn cobs as the raw material for cellulosic ethanol. The primary advantage is the huge supply of corn cobs. In 2008, the United States produced 88 million acres of corn and corn cobs. However, up to now cobs have been harvested from only seed corn acres which accounts for roughly 250,000 acres (POET, 2007). Cob production and harvesting can fit into current Midwest practices. Midwestern farmers do not have to start over learning how to produce different feedstocks such as switch grass or muscanthes. Corn has been grown in the Midwest (for more than 150 years) and familiarity based on long experience offers a comfort level to corn farmers.

The technology also allows the producer to use the modern infrastructure developed over the last twenty years to collect cobs as grain bins, tractor-trailers and combines can be used in the process to with little or no modifications to the commonly used equipment. Seed corn companies have spent years of research and millions of dollars on seed corn genetics contributing to higher yields of corn. These higher yields provide the opportunity for farmers to produce more corn and subsequently more cobs; however, research on using corn cobs to produce ethanol has not received the funding that other potential sources of cellulosic feedstock such as switchgrass and muscanthes have received.

Corn cobs can provide an ethanol plant with a more consistent feedstock compared to alternatives such as corn stover (POET). Corn cobs are uniform, whereas corn stover is an uneven mixture of stalks, leaves, and cobs. Consistency is an important input when processing raw material for producing ethanol; the more consistent the feedstock, the more efficient the production of ethanol. Each batch of cobs would be consistent and eliminate the need for adjustment or for multiple processes. Corn cobs have a high carbohydrate content that feeds the yeast to produce ethanol.

The process of producing ethanol from corn cobs is different than producing ethanol using corn kernels and requires changes from the traditional method of using corn as the feedstock. Existing ethanol plants need to be transformed into plants that will use both kernels and cobs as feedstocks. The two feedstocks will be processed separately, but the end result will be the production of ethanol. The following flow chart (3.4) shows the method of producing ethanol using corn cobs too.

Figure 3.4: Ethanol from Corn Cobs

(POET, 2007)

An additional advantage to using cobs as a feedstock is that they are the same distance from ethanol plants as corn. This allows for a more productive use of current infrastructure: transportation, equipment, farm to market roads, plant offices, plant scales, etc. The effective use of current infrastructure lowers the cost of cellulosic raw material compared to alternative cellulosic sources that might require investment in different logistical systems. Complete utilization of cobs can also lower ethanol plant costs. The waste from the cobs after the ethanol has been produced can be used in a solid fuel boiler to offset the need for natural gas. Water that is currently being used to cool different processes at the plants can be reused, resulting in more production of ethanol with the same amount of waste water being produced. Finally, ethanol produced per acre of corn will increase. It will still take the same amount of energy to produce but the output of ethanol per acre will be greater. It is estimated that by using corn and corn cobs, 18 percent more ethanol will come from a bushel of corn plus cobs (Mayberry, 2007).

3.2 Problems associated with cobs

There are negative aspects of using corn cobs as a feedstock for ethanol. Cobs have been collected for a long time, but these cobs are used for abrasives, fertilizer and insecticide carriers and various other small-scale uses. Collection has been done mostly from seed corn acres on a limited basis. Most modern American corn farmers have never collected cobs. Producers tend to view the cob as a waste product. But many farmers have an entrepreneurial attitude and an attractive price should provide enough encouragement for them to collect cobs. POET facilities that are experimenting with cob use as a feedstock are also working to educate and promote this alternative method of ethanol production through focus groups, customer meetings and large scale public relations events. Overall, interest from farmers is quite high, but some producers remain skeptical of the feasibility of the process.

Equipment used to collect cobs is primitive and, for the most part, untested for commercial use. The focus of the major equipment builders has been on the harvesting of corn. They have designed the combine to be a highly specialized piece of machinery that can harvest several crops with different headers. Equipment manufacturers have not designed combines to harvest cobs. Specialized corn cob collection machinery would require expensive development efforts and new factories and manufacturing equipment. However, if profitable enough, equipment manufacturers will build cob collection capabilities into their combines. The problem is until cobs are proven to be economically viable, the manufacturers will be unwilling to commit resources to design and build cob collection equipment. Equipment manufacturers are exploring cob collection methods to make sure that they do not miss a new opportunity in equipment manufacturing.

Transportation of corn cobs is another issue. Corn cobs have a very low bulk density (17 lbs/ cu. ft. verses 45 lbs/cu. ft. for corn) resulting in high volumes of material to fill a truck to the maximum axle weight. In Iowa, the legal gross weight of a truck is 80,000 lbs. The low bulk density can cause a need for the use of very long and high sided trucks. Most farmers now own a hopper bottomed grain truck that has short sides (Taylor, 2007). The transportation of corn cobs is impractical with current trucks. Farmers may need to purchase more specialized trailers with higher sides and longer trailer length.

3.3 Addressing the concerns of implement manufacturers

The adoption of cob collection is dependent on implement manufacturers. Because cob technology is an entirely new method of production, major implement manufacturers have a stake in the process. Two methods have been tested by POET: a cob caddy and a corn cob mix. Uncertainty exists as to the method that will best meet the needs of farmers' operations. Furthermore, equipment manufacturers need to be convinced that cob based cellulosic ethanol production warrants investment in developing collection equipment. Confidence will be gained through testing new equipment and testing modifications to existing equipment and analyzing costs and returns. Demand for such equipment is dependent on farmers' acceptance. The endorsement of farmers will give implement manufacturers the incentive to go ahead. POET is working with some of their farmer/owners to test methods of cob collection to "find optimal solutions" (Corn cob ethanol, 2007). Testing will determine if these collection methods work and analysis will be done to see if they are economically viable. Local farmers will need to be convinced that cob collection is profitable. Until testing is completed, farmers will remain skeptical. Without a demonstration of full scale ethanol production from corn cobs and reliable analysis to show a positive financial return for the equipment, implement manufactures will resist producing corn cob harvesters. Both equipment manufacturers and farmers need profit from cob based cellulosic ethanol production in order for the system to be adopted.

3.4 Addressing the concerns of the producer

POET must address farmers' concerns about cob collection in order to gain their support. Producers have indicated that they are concerned about collection and storage, as well as logistics and infrastructure. POET is working to address farmers' concerns including different collection options that can be used to establish profitable collection and storage of cobs.

Two possible solutions to the storage problem exist. The first is a ground pile. Corn cobs could be collected and stored in a pile that remains on the bare ground open to the elements. The cobs will be subjected to harsh weather conditions. The consequence of this storage system has not yet been determined. The early indication is that corn cobs will have quality deterioration. Potential solutions exist in the use of permanent structures, such as machine sheds, hoop buildings and other corn crib type structures. The negative of this type of storage is that if the structures don't already exist the farmer is required to make high capital investments with the potential for only low rates of return.

Transportation and logistics is another area that is unproven for cob based ethanol production. On the face of it, transportation of cobs is more efficient and requires less space than corn stover. The corn cob is the second densest part of the plant, with the corn kernel being the densest. POET uses techniques to make cobs even denser to reduce the space required to transport them (Corn cob ethanol, 2007). The infrastructure required to transport cobs is already in place, but it is unknown if existing transportation capacity can also handle the necessary volume of cobs.

Most of the solutions that have been presented are farmer dependent. As businessmen and women, farmers have to be shown the profitability for them of corn cob ethanol production. Issuing multi-year contracts for the purchase of corn cobs is one way to provide an incentive for the farmer harvest of cobs. Focus groups have uncovered that POET would share the risk and reward with farmers. Test harvests that allow farmers to try the equipment and judge the efficiency while POET provides fuel and manpower is one way POET can generate interest. Implement manufacturers have to know that farmers are willing to pay for new equipment or modifications to current implements. Assurance could result in more timely production or conversion of the equipment necessary to harvest corn cobs.

Farmers in general are very efficient in their operations. The early versions of cob collection equipment are not very efficient. The new equipment will be bulky and clumsy at first but should become more efficient and streamlined as time goes by, the natural progression of all new technologies. It will be the same for the price of the equipment: high at first and then dropping as equipment manufactures develop and build a larger volume of equipment. In most cases, the producer will need additional manpower and equipment to harvest cobs too. Additional labor may be hard to find in rural areas. This labor demand will more than likely be for temporary seasonal help for the fall harvest which could make the prospect less desirable to many because of the scarce amount of good help during that time of year. Additional costs to an operation for cob collection must be factored in to determine profitability for farmers.

3.5 Addressing the concerns of current cob consumers

Currently only a handful of companies use corn cobs in the state of Iowa. The largest and most notable is Green Products, located in Conrad, Iowa. They buy 50,000 tons to process for many uses from bedding to pharmaceuticals. Best Cob, located in Independence, Iowa, uses roughly 30,000 tons of cobs every year. Local cattle producers also use corn cobs for bedding and, more importantly, feed. Currently those three business entities get all their cobs from seed corn companies; none of the cobs come from field corn.

CHAPTER 4: METHODOLOGY

There are several different tools to analyze investment decisions. The main objective for the producer is to determine if an investment will be profitable. The following methods are used to evaluate cob harvesting equipment for the producer: Net Present Value (NPV), Internal Rate of Return (IRR) and payback period.

4.1 Net Present Value

NPV is defined as the net present value of discounted cash flows associated with an investment. The NPV method involves discounting all cash outflows and inflows to present values. A dollar received in the present is more valuable than a dollar received in the future due to the ability to reinvest that dollar. Present value decreases longer out the dollar is in the future and the higher the discount rate. The NPV will determine the value of the investment in today's dollars. The formula for NPV is Rt/ (1+i) t where t is the time of the cash flow, i is the discount rate (the rate of return that could be earned on an alternative investment with similar risks, Rt is the net cash flow (the amount of cash, inflow minus outflow) at time t. The decision rule is that if NPV is positive the investment should be undertaken.

4.2 Internal Rate of Return

IRR is a rate of return used to measure and compare the profitability of investments. The IRR of an investment is the interest rate which makes discounted cash inflows just equal to discounted cash outflows. IRR can be used when firms set a minimum rate of return or hurdle rate of return for investments.

4.3 Payback period

The payback period is the amount of time it takes for an investment to generate enough cash flow to repay the original investment. Payback period is a simple calculation that only takes into effect the cash inflows until the investment is repaid and does not take into effect any future cash flows including cash flows beyond the payback period which could make an investment better or worse.

All three methods will be used to assess the viability in cob collection methods on acres of production only. I will include two years of subsidies which are currently in the current farm bill. Future subsidies are not included.

CHAPTER 5: ECONOMIC ANALYSIS OF USING CORN COBS

The economics underlying corn cob collection is difficult to assess because there are several unknowns in the process of cob collection. It will be necessary to make some assumptions. There are two methods of cob collection currently being investigated by POET Biorefining: corn cob mix and towing a cob cart behind the combine. POET has stated that it will pick up the cobs at the farmers field and pay farmers between $30-60 per dry ton (DT). The farmer is responsible for collecting and piling the cobs in one pile per field. The 2008 Farm Bill has included a provision for a $45 per ton payment to farmers for up to two years of the five year life of the Farm Bill (U.S. Department of Agriculture, 2008). Current cob yield estimates show that a harvest of 150 bushel per acre corn will yield 0.634 DT of cobs per acre. These estimates take into account a 90% capture rate for the cob. This yield is assumed through all cob collection methods and economic models.

5.1 Corn cob mix

The first method of cob collection is the corn cob mix (CCM). This method is currently used sparingly in Europe and by some cattle farmers in the United States. The CCM is created by adjusting settings on the combine. The corn and the cobs are collected together in the grain tank of the combine. After unloading the grain tank, the cobs and corn are separated into corn and cobs for use in ethanol production. This can be done in several different ways but the method most commonly used is a rotary screener. The screener diverts the corn stream to the grain truck and the cobs to the ground. The screening can be done anywhere that the farmer wants the cob pile, most often in the field. The CCM is a very simple process and the only additional equipment needed is a rotary screener

($25,000-$65,000). It requires little investment and smaller producers seem to prefer this option more than the larger producers. The major disadvantage is that the CCM process reduces the per hour harvest capacity of a producer’s combine. A large volume of material needs to be processed through the combine, which means the combine has to be run at a slower speed. This reduces harvest capacity approximately 10 to 20 percent. It also takes additional time to screen the material for separation. There is need for more manpower. The additional manpower for CCM is needed to run the screener at least until the equipment designers improve screening technology.

Figure 5.1: Corn Cob Mix

(Mayberry, 2008)

Figure 5.2: Collection Corn Cob Mix

(Mayberry, 2008)

Figure 5.4: Rotary Screener

(Mayberry, 2008)

5.2 Cob wagon

The other method of cob collection is to tow a cob wagon behind the combine. The combine is set to harvest the grain from the plant in the normal way. The wagon behind the combine then separates the cobs from the rest of the material. A combination of air direction and speed causes lighter weight materials, the husk and the stalk, to blow away from the heavier cobs back onto the field. The cobs are collected in the wagon until they are dumped either into a collection wagon or in a pile at the end of the field. The main advantage is that the combine does not have to slow down. The volume of material that runs through the combine is no different than normal. Pulling a wagon behind the combine is a disadvantage because producers are not accustomed to having something behind the combine in the field. The wagon, at a certain point in collection, will need to be dumped which takes time away from harvesting the crop.

With both collection systems, cobs are collected and stored in a pile at the end of the field to be picked up at a later time by a third party and the corn is transported as normal either to the local elevator or to farm storage.

Figure 5.3: Cob Collections with Wagon

(Mayberry, 2008)

5.3 Economics

There are several variables that need to be considered to develop an economic model. POET estimates a 5 to 10 percent reduction in harvest capacity to collect cobs, which results in a cost of $1.13 to $2.25 per acre, assuming the cost of running a combine to be $22.50/acre. Pulling a cob cart or running a screener requires more fuel. POET estimates that the farmer will use 0.4 gal more fuel per acre which will cost the farmer $1.60 per acre at a diesel cost of $4.00. The cob cart or screener requires an extra 2 to 3 minutes to unload; therefore increasing harvest time by 15 to 25 percent, costing roughly $3.50- $5.00 per acres. The following analysis will be completed for two different sized producers, 1000 acres and 750 acres.

Table 5.1 shows the gross income per acre for levels of harvested acres. No expenses have been taken out.

Table 5.1: Gross Cob Income

Gross income per acre for corn cobs, using conversion of .634 bone dry tones of cobs per acre

Corn Acres	$40/ton	$45/ton	$50/ton	$60/ton	$70/ton	$80/ton	$90/ton
100	$2,536	$2,853	$3,170	$3,804	$4,438	$5,072	$5,706
200	$5,072	$5,706	$6,340	$7,608	$8,876	$10,144	$11,412
300	$7,608	$8,559	$9,510	$11,412	$13,314	$15,216	$17,118
400	$10,144	$11,412	$12,680	$15,216	$17,752	$20,288	$22,824
500	$12,680	$14,265	$15,850	$19,020	$22,190	$25,360	$28,530
750	$19,020	$21,398	$23,775	$28,530	$33,285	$38,040	$42,795
1000	$25,360	$28,530	$31,700	$38,040	$44,380	$50,720	$57,060
2000	$50,720	$57,060	$63,400	$76,080	$88,760	$101,440	$114,120
3000	$76,080	$85,590	$95,100	$114,120	$133,140	$152,160	$171,180
5000	$126,800	$142,650	$158,500	$190,200	$221,900	$253,600	$285,300

If a producer harvested 1000 acres of corn and received $45/ton for cobs his gross revenue for that process would be $28,530 at $90/ton it would be $57,060.

Table 5.2: Cob Wagon net income and after deducting expenses

Corn Acres	Extra cost per acre for pull wagon	Net Income-$90/acre	Corn Acres	Extra cost per acre for pull wagon	Net Income-$45/acre
100	$968.00	$4,738.00	100	$968.00	$1,885.00
200	$1,936.00	$9,476.00	200	$1,936.00	$3,770.00
300	$2,904.00	$14,214.00	300	$2,904.00	$5,655.00
400	$3,872.00	$18,952.00	400	$3,872.00	$7,540.00
500	$4,840.00	$23,690.00	500	$4,840.00	$9,425.00
750	$7,260.00	$35,535.00	750	$7,260.00	$14,137.50
1000	$9,680.00	$47,380.00	1000	$9,680.00	$18,850.00
2000	$19,360.00	$94,760.00	2000	$19,360.00	$37,700.00
3000	$29,040.00	$142,140.00	3000	$29,040.00	$56,550.00
5000	$48,400.00	$236,900.00	5000	$48,400.00	$94,250.00
Notes:			Notes:		
7% reduction to harvest crop-$22.50 combine hour		$1.58	7% reduction to harvest crop-$22.50 combine hour		$1.58
.4 gal/acre additional fuel @ $4/gallon		$1.60	.4 gal/acre additional fuel @ $4/gallon		$1.60
Additional harvest time-$5/acre		$5.00	Additional harvest time-$5/acre		$5.00
Additional labor $1.50/acre		$1.50	Additional labor $1.50/acre		$1.50
Total expense per acre		$9.68	Total expense per acre		$9.68
Income/acre		$90.00	Income/acre		$45.00

Table 5.3: CCM net income and expense 1000 acre producer

Corn Acres	Extra cost per acre for CCM	Net Income-$90/acre	Corn Acres	Extra cost per acre for CCM	Net Income-$45/acre
100	$2,038.00	$3,668.00	100	$2,038.00	$815.00
200	$4,076.00	$7,336.00	200	$4,076.00	$1,630.00
300	$6,114.00	$11,004.00	300	$6,114.00	$2,445.00
400	$8,152.00	$14,672.00	400	$8,152.00	$3,260.00
500	$10,190.00	$18,340.00	500	$10,190.00	$4,075.00
750	$15,285.00	$27,510.00	750	$15,285.00	$6,112.50
1000	$20,380.00	$36,680.00	1000	$20,380.00	$8,150.00
2000	$40,760.00	$73,360.00	2000	$40,760.00	$16,300.00
3000	$61,140.00	$110,040.00	3000	$61,140.00	$24,450.00
5000	$101,900.00	$183,400.00	5000	$101,900.00	$40,750.00
Notes:			Notes:		
15% reduction to harvest Crop-$22.50 combine hour		$3.38	15% reduction to harvest Crop-$22.50 combine hour		$3.38
Run screener .06/bu * 175 bu/acre		$10.50	Run screener .06/bu * 175 bu/acre		$10.50
Additional harvest time-$5/acre		$5.00	Additional harvest time-$5/acre		$5.00
Additional labor $1.50/acre		$1.50	Additional labor $1.50/acre		$1.50
Total expense per acre		$20.38	Total expense per acre		$20.38
Income/acre		$90.00	Income/acre		$45.00

Cash flow is calculated by assuming an original investment of $100,000 for a wagon and $65,000 for a CCM screener, with revenue in year one and two of $57,060 (1000 acre farmer receiving $45/ton from subsidies and $45/ton from the processor). Year's 3-5 farmers receiving $45/ton for a gross of $28,530.

Table 5.4: NPV and IRR 1000 Acre Producer

1000 acre farmer, $45/ton with two years of subsidies. Two years of $90/ton Three years of $45/ton.

Cash flow with additional expense taken out

	Wagon	CCM
Year 0	-$100,000	-$65,000
1	$47,380	$36,680
2	$47,380	$36,680
3	$18,850	$8,150
4	$18,850	$8,150
5	$18,850	$8,150

Wagon Interest	NPV 3 year	NPV 5 year
8%	($504.79)	$27,120.35
7%	$982.35	$30,096.44
6%	$2540.54	$33,240.14
5%	$4173.53	$36,562.56
IRR	8.0%	21.0%

CCM	NPV 3 year	NPV 5 year
8%	$6370.26	$18,511.62
7%	$7449.47	$20,247.87
6%	$8577.11	$22,075.34
5%	$9755.67	$23,999.76
IRR	15%	24.0%

Simple Payback period for wagon without subsidies 5.30 years ($100,000/$18850)

Simple payback period for wagon with subsidies 2.3 years ($100,000/ (year 1and 2 revenue and 3 months of year 3 revenue)

Simple payback period for CCM Unit without subsides is 7.9 years ($65,000/8150)

Simple payback period for CCM Unit with subsides is 1.77 years ($65,000/36680)

This is just an example of a cash flow for one operation. Below is an example of a cash flow for a 750 acre producer. Every operation will be different but cob collection can have a positive effect for the right sized producer.

Table 5.5: Cob wagon net income and expense 750 acre producer

Corn Acres	Extra cost per acre for pull wagon	Net Income-$90/acre	Corn Acres	Extra cost per acre for pull wagon	Net Income-$45/acre
100	$968.00	$4,738.00	100	$968.00	$1,885.00
200	$1,936.00	$9,476.00	200	$1,936.00	$3,770.00
300	$2,904.00	$14,214.00	300	$2,904.00	$5,655.00
400	$3,872.00	$18,952.00	400	$3,872.00	$7,540.00
500	$4,840.00	$23,690.00	500	$4,840.00	$9,425.00
750	$7,260.00	$35,535.00	750	$7,260.00	$14,137.50
1000	$9,680.00	$47,380.00	1000	$9,680.00	$18,850.00
2000	$19,360.00	$94,760.00	2000	$19,360.00	$37,700.00
3000	$29,040.00	$142,140.00	3000	$29,040.00	$56,550.00
5000	$48,400.00	$236,900.00	5000	$48,400.00	$94,250.00
Notes:			Notes:		
7% reduction to harvest crop-$22.50 combine hour		$1.58	7% reduction to harvest crop-$22.50 combine hour		$1.58
.4 gal/acre additional fuel @ $4/gallon		$1.60	.4 gal/acre additional fuel @ $4/gallon		$1.60
Additional harvest time-$5/acre		$5.00	Additional harvest time-$5/acre		$5.00
Additional labor $1.50/acre		$1.50	Additional labor $1.50/acre		$1.50
Total per acre		$9.68	Total per acre		$9.68
Income/acre		$90.00	Income/acre		$45.00

Table 5.6: CCM net income and expense 750 acre producer

Corn Acres	Extra cost per acre for CCM	Net Income-$90/acre	Corn Acres	Extra cost per acre for CCM	Net Income-$45/acre
100	$2,038.00	$3,668.00	100	$2,038.00	$815.00
200	$4,076.00	$7,336.00	200	$4,076.00	$1,630.00
300	$6,114.00	$11,004.00	300	$6,114.00	$2,445.00
400	$8,152.00	$14,672.00	400	$8,152.00	$3,260.00
500	$10,190.00	$18,340.00	500	$10,190.00	$4,075.00
750	$15,285.00	$27,510.00	750	$15,285.00	$6,112.50
1000	$20,380.00	$36,680.00	1000	$20,380.00	$8,150.00
2000	$40,760.00	$73,360.00	2000	$40,760.00	$16,300.00
3000	$61,140.00	$110,040.00	3000	$61,140.00	$24,450.00
5000	$101,900.00	$183,400.00	5000	$101,900.00	$40,750.00
Notes:			Notes:		
15% reduction to harvest Crop-$22.50 combine hour		$3.38	15% reduction to harvest Crop-$22.50 combine hour		$3.38
Run screener .06/bu * 175 bu/acre		$10.50	Run screener .06/bu * 175 bu/acre		$10.50
Additional harvest time-$5/acre		$5.00	Additional harvest time-$5/acre		$5.00
Additional labor $1.50/acre		$1.50	Additional labor $1.50/acre		$1.50
Total expense per acre		$20.38	Total expense per acre		$20.38
Income/acre		$90.00	Income/acre		$45.00

Table 5.7: NPV and IRR 750 Acre Producer

750 acre farmer, $45/ton with two years of subsidies. Two years of $90/ton Three years of $45/ton.

Cash flow/additional expense taken out

	Wagon	CCM
Year 0	-$100,000	-$65,000
1	$35,535	$27,510
2	$35,535	$27,510
3	$14,138	$6,113
4	$14,138	$6,113
5	$14,138	$6,113
salvage	$5,000	$2,500

Wagon		
Interest	NPV 3 year	NPV 5 year
8%	($23,526.74)	($2,078.52)
7%	($22,627.72)	($13.72)
6%	($21,679.50)	$2,176.52
5%	($20,679.38)	$4,500.75
IRR	-9.0%	7.0%

CCM	NPV 3 year	NPV 5 year
8%	($10,268.60)	($797.90)
7%	($9,599.81)	$388.21
6%	($8,897.35)	$1,641.98
5%	($8,159.44)	$2,967.81
IRR	-4.0%	7.0%

Table 5.5 is an example of a 750 acre producer. The smaller producer cannot make the wagon work but does make a little income with the CCM unit over five years. The simple payback period for the wagon without subsidies is 7.07 years ($100,000/$14,138). The simple payback for the wagon with subsidies is just over 4 years. The simple payback for

the CCM unit without subsidies is 10.6 years ($65,000/$6113) and with subsidies is 3.7 years.

Table 5.4 and 5.7 show the difference that just 250 acres can have on a producers operation. Net revenue will be very sensitive to acres farmed.

CHAPTER 6: CONCLUSION

The technology of collecting cobs for cellulosic ethanol has come a long way in a very short amount of time. It is expected further advances will change the economics in the future.

The CCM process was the first method used. At the time, it was thought to be the simplest and most efficient method available to the producer. Research and technological advances have shown otherwise. Although CCM is viable method, it is no longer the preferred method. A major problem is that there is not commercial grade screener available today for farmers to use on farm. Secondly, the amount of material that needs to be processed through the combines is too great. Today's combines will work with this process, but they were not made for the application so there have been premature parts failures and possible reduction in combine life. The solution seems to be to reduce the material processed by the combine. CCM can be an option, but there obstacles.

A cob cart pulled by the combine seems to be the current method, but it shares some efficiency problems with the CCM method of collection. A separate catch cart for the cobs might work, but it would require another tractor, wagon, and person. Trials show that it is difficult to run the extra cart. Ethanol processors prefer the cob cart because it produces clean cobs that are easier to store and process. But the producers still have to be convinced to use this method.

The smaller producers, less than 750 acres, are going to struggle to profitably cob with either method. They may need to partner with other smaller producers in order to collect cobs profitably. The data show that the larger producers, more than 750 acres, can make either system work, but pulling the wagon would be preferred. With either system, producers will need to have long term contracts in order for collecting cobs to be viable.

Other technologies such as square balers pulled by combines are being researched. This method is similar to pulling a cob wagon, but it does not require additional labor. The baler concept is more like a custom bale pickup operation. A farmer can combine his corn as normal and the bales can be picked up at a later date. Farmers appear willing to adopt this method of cob collection, because it requires little change in the way corn is harvested. Plus, most farmers have had experience with bales

This is just one example of adoption of technology that has come about because of cellulosic ethanol. The future of cellulosic ethanol depends on good working relationships between ethanol producers and corn farmers.

The Renewable Fuels Standard requires the use of renewable fuels to produce 36 million gallons of fuel by the year 2022. As the need for alternative energy sources continues to increase, energy producers are mandated to use alternative methods to produce ethanol. Although there are many variables to consider and much testing and research yet to be done, the collection and processing of corn cobs is a fundamentally sound concept that could allow the mandated goal to be reached. Increasing the value of an acre of corn by utilizing what has been considered a waste product can benefit farmers by increasing profit per acre for farming operations. A key to making cellulosic ethanol work will be to make growing and collection cellulosic materials including corn cobs profitable for farmers.

As cellulosic ethanol mandates come into effect to meet the requirements of the RFS, all ethanol plants will have to consider incorporating cellulosic technologies to make ethanol. Facilities that are forward looking are researching alternative feed stocks and collection methods now. They have to be prepared to meet government requirements and help the U.S. become more energy secure. Technology will be developed to increase cellulosic ethanol productive capacity to include many non-traditional feedstocks in ethanol production. Cobs can be a vital part in the future of cellulosic ethanol.

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