Chapter 3
Ethanol Economics of Dry Mill Plants

Vernon R. Eidman[3]

This chapter provides estimates of the cost of building new ethanol plants and the cost of producing ethanol in those plants. Fuel ethanol can be produced from various feedstocks including starch, sugar and cellulose. Ninety-seven percent of ethanol production in the United States is produced from corn and 2.5 percent is produced from grain sorghum, because they are the lowest cost sources of starch that are available in abundant supplies. The remaining 0.5 percent is produced from whey from cheese plants (Renewable Fuels Association). Ethanol produced from other sources of starch (including wheat, barley, rye and potatoes) and sugar (sugar cane and sugar beets) is more costly given the usual market price relationships that exist among these commodities. The methods of producing ethanol from cellulose are not as well developed and result in more expensive ethanol than using corn and grain sorghum as the feedstock. Improvements in conversion technology are expected to reduce these costs over time; making ethanol produced from cellulosic feedstocks (including crop residues, woody species, and energy crops) a major source of fuel at a competitive price. This chapter focuses on the costs of producing fuel ethanol from corn because that is the most commonly used feedstock in Illinois at the current time, and it is likely to be the most economical feedstock for commercial ethanol production in Illinois until cellulosic ethanol becomes cost competitive with corn.

This chapter focuses on dry mill ethanol production because most of the existing plants use dry mill technology and most of the future expansion is expected to use dry mill technology. Dry mill plants produce about 82 percent of total U.S. ethanol production and specialize in producing one product, ethanol, from the starch that is processed. Wet mills produce the remaining 18 percent of U.S. production. They have higher investment costs and usually have the flexibility to produce corn starch, high fructose corn syrup or ethanol from the starch that is processed.

The next section of this chapter provides a brief explanation of the dry mill production process. The remaining sections discuss considerations in selecting a site to build an ethanol plant, provide estimates of the investment costs to build and bring a new plant into production, and the estimated cost per gallon of ethanol produced for two common sizes of plant. An example of the procedure used to estimate the costs in this paper is presented and the URL to access an electronic version of the spreadsheet is given. The discussion considers the breakeven costs of using coal instead of natural gas as the boiler fuel, and the expected annual return to equity holders for a 50 million gallon per year plant with alternative combinations of corn and ethanol prices. The final section contrasts the amount 50 and 100 million gallon per year plants can pay for corn and earn a specified return to equity capital.

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[3] Professor Emeritus, Department of Applied Economics, University of Minnesota, St. Paul, MN.

Dry Mill Ethanol Production

Figure 1 provides an overview of the dry mill ethanol production process and the products produced. A brief description of each processing step is given below.[4]

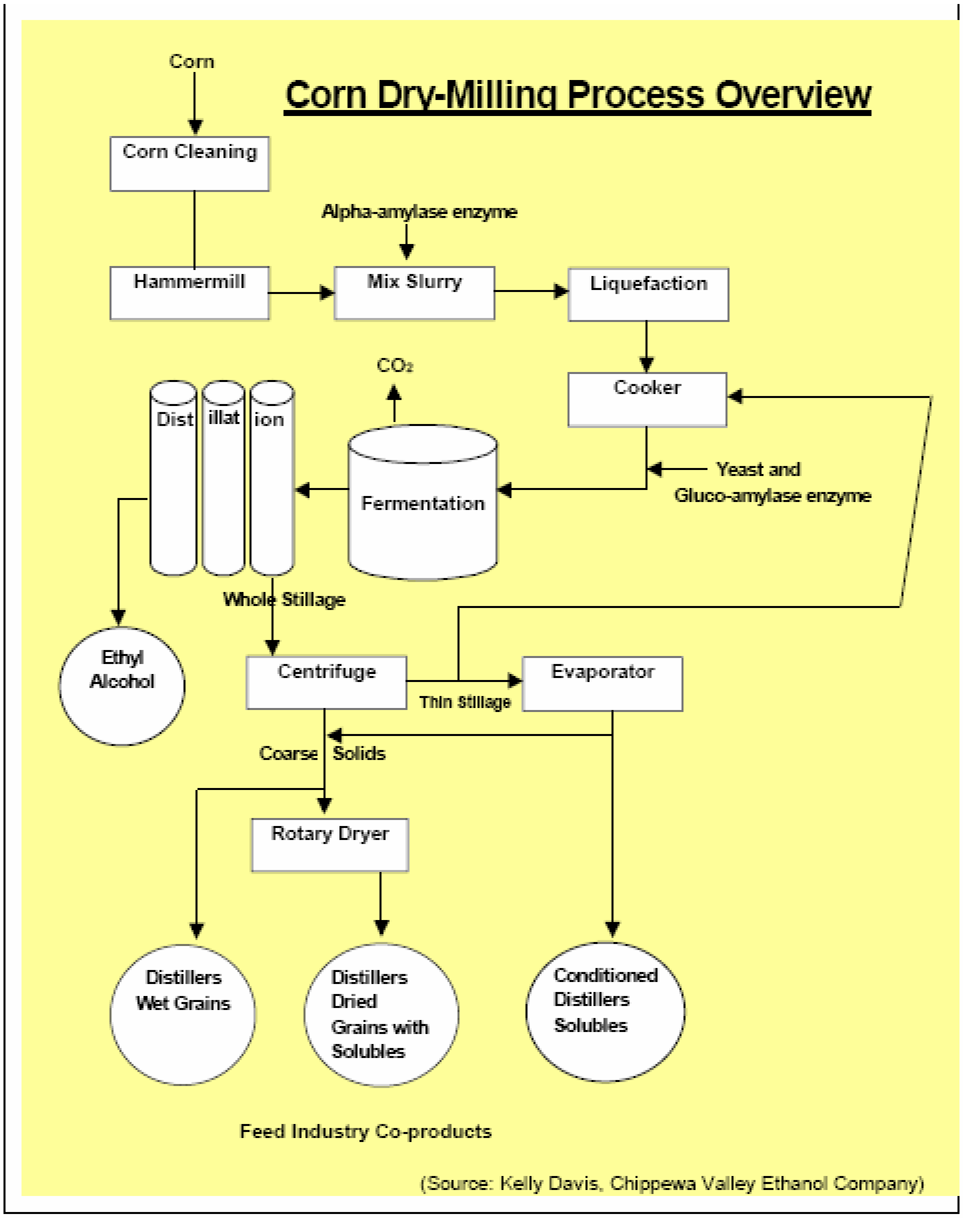

Figure 1. Dry-Mill Ethanol Production Process

Cleaning and Grinding: The incoming corn is inspected to be sure it is free of mold, cleaned of any foreign material, and ground to a fine powder to expose the starch.

[4] This section is based on material in Tiffany and Eidman and *The Ethanol Handbook*.

Liquefaction: The corn meal is mixed with water and the enzyme alpha-amylase. This mixture is heated to 120 to 165 degrees C to kill bacteria and then held at a lower temperature (90 degrees C) to liquefy the starch.

Saccharification: The mash from the cookers is cooled and the secondary enzyme glucoamylase is added to convert liquefied starch to fermentable sugars in a process called saccharification.

Fermentation: Yeast is added to the mash to ferment the sugars, producing ethanol and carbon dioxide. The action of the yeast produces heat, making it necessary to cool this tank and maintain the pH of the mash as the fermentation progresses. Carbon dioxide is produced and can be collected, chilled to a liquid and sold if the plant has a buyer for the CO_2. Many plants do not have a buyer and allow the CO_2 to go into the atmosphere.

Distillation: The fermented mash, called beer, contains about 10 percent alcohol as well as all the non-fermentable solids from grain and the yeast. The beer is pumped to a continuous flow, multiple column distillation system where the alcohol is removed from the solids and water. The mixture leaving the top of the final column is hydrous ethanol composed of approximately 95 percent alcohol and 5 percent water. The residual mash, called stillage, is transferred to the centrifuge which divides the stream into thin stillage and coarse solids.

Dehydration: The hydrous alcohol is passed through molecular sieves to remove the remaining water. The molecular sieves consist of ceramic beads. The remaining water in the hydrous ethanol is captured on the beads as the vaporized ethanol solution passes through the sieves, producing anhydrous ethanol.

Denaturing: Ethanol used for fuel is denatured with 2 to 5 percent of a low cost hydrocarbon that makes the denatured fuel unfit for human consumption. The industry often uses natural gasoline, derived from natural gas, or raffinate. They have low octane, but that is not a problem since ethanol has an octane of 113.

Distillers Grains and Solubles: The residual is centrifuged to separate the liquid from the distillers grains. The liquid, referred to as thin stillage, is heated to remove water and concentrate the soluble materials. This process increases the percent solids from about 7 percent in the thin stillage to approximately 30 percent. The concentrated liquid is referred to as syrup. The distillers grains can be sold after centrifuging or pressing and fed wet (at about 65 percent moisture) within a period of several days to either dairy or beef cattle. In most situations the distillers grains are dried in rotary drum driers and the concentrated syrup is mixed in during the drying process. Alternatively, the syrup can be sold separately as livestock feed or for other uses.

Site Considerations

Selecting an appropriate site is an important step in developing a profitable ethanol plant. Some of the major site location factors that should be considered in making the selection are discussed in this section. Publications providing a more detailed discussion of this topic are listed in the references (Kotrba and Minnesota Department of Agriculture).

Feedstock supply. The cost of the corn is the largest cost item in the production of ethanol. Locating the plant in an area with access to a relatively low-cost supply of corn is an important aspect of profitable ethanol production. Many plants located in major corn producing areas in the Midwest identify a site in an area that produces much more corn than is currently used for livestock and industrial uses within the area. One rule of thumb is to locate the plant where the plant will not use more than 50 percent of the exportable corn from the area, so that purchases by the plant will not greatly alter the local corn basis (Kotrba). It is important to consider other users who may be moving into the area (other ethanol plants and large livestock feeding operations) when making this calculation. Identifying sites that meet these qualifications is becoming increasingly difficult as more ethanol plants are sited.

Availability of energy. The cost of boiler fuel is typically the second largest cost in ethanol production. Availability of a reliable and relatively low cost supply of boiler fuel and electricity is very important in attaining low cost production. Locating close to a natural gas pipeline or to a coal source that purchases coal in unit train loads is usually important to obtain fuel at a low cost. As plants begin to use biomass for boiler fuel, it will be important to locate the plant close to the source of the biomass to minimize transportation costs.

Water supply and natural resources. Grain ethanol plants require 3 to 5 gallons of good quality water per gallon of ethanol produced. For example, a plant producing 60 million gallons of ethanol per year will require a minimum of 180 million gallons of water per year, and may require as much as 300 million gallons. Most of the water used by the plant is released as water vapor. There may also be other considerations, such as natural resource features which prevent removal of the needed water from an aquifer because of its impact on surrounding lakes and streams. Concern for endangered species also may prohibit location of a plant in some areas.

*Wastewater disposal***.** It is important to become familiar with the potential barriers to disposing of the wastewater from the proposed ethanol plant. State Pollution Control Agencies provide information on water quality problems in the area as well as requirements that must be met in disposing the waste water.

Transportation. The major options to bring corn to the plant and transport ethanol and distillers grains away from a proposed ethanol plant are truck and rail, and in some locations, river barges. Ethanol plants substantially increase vehicle traffic on state and local roadways throughout the year. Rail options are often attractive when large amounts of corn must be brought to the facility from outside of the local area, and to transport ethanol and distillers grains to distant markets. Locating the facility on a main rail line rather than a short line avoids switching cars, and usually reduces rail costs. Careful consideration of whether the roads, rail lines and barge facilities are adequate to meet the transportation needs is an important aspect of selecting the location for the plant.

Local site issues. Most ethanol plants are located in rural areas without nearby industrial facilities. A plant can significantly affect local residents through air emissions, increased traffic, dust from traffic and plant operations, noise, odor, and light from nighttime operations. An additional consideration is selecting a site that is large enough to permit future expansion of the plant. Some early ethanol plants were abandoned because the site was too small to accommodate an expansion required for the plant to remain cost competitive.

Community relations. Maintaining effective communications with local residents of a proposed site will reduce the chance of strong opposition to the project. Misunderstandings among local residents frequently result from a lack of timely and accurate information. Personal contacts and spending time in the early stages listening to residents concerns can be beneficial in the longer run. Providing updates with Web sites, periodic mailings, information meetings, and clearly worded releases to local news media are additional methods to maintain communication with the local residents.

Grain Ethanol Production Costs

The standard ethanol plant that is currently being built in the Midwestern United States is a natural gas fired dry mill plant that processes corn and produces denatured ethanol, dried distillers grains with solubles (DDGS) and CO2. Most Midwest plants sell two products, denatured ethanol and DDGS, but do not have a market for the CO2 which is vented. The standard plant has a rail siding to handle the loading and unloading of rail cars, and 10 days of storage capacity for corn, ethanol and DDGS. The initial investment includes funds to pay for the legal fees associated with the project, purchase of the building site, obtaining the required permits, developing the water supply, the dirt work, plant construction, starting the plant, and the initial operating capital (usually 10 percent of the total).

Plants may decide to modify this standard plant to take advantage of local conditions and to augment the capacity to implement their unique production and marketing strategies. For example, some plants do not build much corn storage because they have arranged for a local elevator to source the corn. Others want to add storage and loading/unloading facilities to accommodate unit trains. And some decide to use alternative boiler fuels, such as coal or biomass. Still other plants want to include equipment to remove the corn oil from thin stillage for sale as a feedstock for biodiesel production, or to install equipment to fractionate the corn as it enters the plant so they can produce a broader range of co-products. These and other changes tend to increase the initial investment costs per gallon of nameplate capacity. The estimates of investment costs presented in this chapter are for the standard plant described above.

Investment Costs

Investment costs are normally quoted per gallon of nameplate capacity. The nameplate capacity is the output in gallons of ethanol per year that the engineering company designing the plant and the construction company building the plant guarantee it will produce. The engineering company guarantees a package of performance characteristics including the minimum number of gallons of anhydrous ethanol the plant will produce per bushel of corn, the maximum amount of energy required per gallon of ethanol produced, and the minimum number of gallons the plant will produce per year. Many operators exceed these guarantees. For example it is customary to exceed the name plate capacity by 10 to 30 percent per year, providing the plant can do so without exceeding the emission limits placed on the plant. The estimates in this chapter assume the plant analyzed produces at 120 percent of name plate capacity, a typical operating rate.

While the general description of a standard plant has not changed much over the past two years, the investment cost per gallon of capacity has increased, the size of the "small plants" being built has increased, and the economies of scale are greater than they were two years ago. In the 2003 through early 2005 period, we estimated the investment costs of natural gas fired plants to be $1.25 per gallon of name plate capacity for a 40 million gallon per year plant and $1.17 per gallon of name plate capacity for a 100 million gallon per year plant (Tiffany and Eidman, and Nicola). The author surveyed lenders and builders of ethanol plants during December 2006 and January 2007 and found that these costs have increased about 50 percent. The cost of a generic natural gas fired plant with a nameplate capacity of 50 million gallons per year is $2.25 per gallon. The investment for a 100 million gallon nameplate capacity plant is $1.80 per gallon. Thus, the current initial investment in a 50 million gallon plant is about $112.5 million, and the investment in building a 100 million gallon plant is $180 million. The major reasons given for the increase in the initial investment over the past two years are the higher costs of stainless steel, copper, steel and concrete; and the additional costs construction firms incur when they must manage a larger number of projects in a given amount of time.

Plants designed to use alternate fuels typically have higher investment costs. Relatively little data is available on the cost of building coal and biomass fired plants. Estimates obtained from construction companies suggest the cost of coal fired plants total $2.95 and $2.45 per gallon of name plate capacity for 50 and 100 million gallon plants, respectively. Firing the boiler with corn stover, DDGS and other biomass is experimental at this time and investment cost data for these alternative fuels are not available.

Cost Per Gallon

The cost of ethanol production for alternative conditions was estimated with the ethanol success spreadsheet (Tiffany and Eidman), available at http://www.agmrc.org/NR/rdonlyres/CBD4DE-8DA0-44F6-A9AE-02320DBF99F6/0/e. An example of the input and output is shown in Figure 2. The example is for a new natural gas fired plant with a name plate capacity of 50 million gallons per year. The spreadsheet has a column for input data and three columns for output, one for cost and returns per bushel of corn, a second for cost and revenue per gallon of denatured ethanol produced, and the final for the annual plant totals. Consider the assumptions of the base case entered in the input column of Figure 2. The plant is assumed to produce 120 percent of name plate capacity, or 60 million gallons per year. In this case the owners are putting up 60 percent equity capital and borrowing 40 percent at an interest rate of 8.75 percent. The owners want a 12 percent rate of return on their equity capital

1	B	C	D	E	F	G	H	I
2	**Ethanol Dry Mill Spreadsheet**		by Douglas G. Tiffany,		University of Minnesota			
3		Cost/Denat. Gal. Ethanol	Ranges for Column C					Plant Totals
4	Nameplate Ethanol Prod. (Denat. Gal.)	50,000,000						
5	Investment per Nameplate Gallon	$2.2500	$1.00- $4.00				Plant Cost	$ 112,500,000
6	Factor of Nameplate Capacity	1.2000	(80%- 150%)					
7	Debt-Equity Assumptions							
8	Factor of Equity	0.60						
9	Factor of Debt	0.40					Initial Debt	$ 45,000,000
10	Interest Rate Charged on Debt	0.0875						
11	Rate of Return Reqd. by Investors on Equity	0.12						
12								
13	Conversion Efficiency Assumptions				Annual Production			
14	Anhydrous Ethanol Extracted (Gal. per Bu.)	2.750	2.5-2.85 gal/bu		Bushels Ground		Denat. Gallons	
15	DDGS per Bushel (lb. per Bu.)	18	15-22 lb./bu		21,381,818		60,000,000	
16	CO2 extracted per Bushel (lb. per Bu.)	18	15-22 lb./bu					
17					Revenue/Bu. Ground		Revenue/Gal. Denatured Sold	Plant Totals
18	Establishment of Gross Margin	Price per Unit						
19	Ethanol Price (denatured price) $/gal.	$1.50	$1.00- $3.00		$4.2092		1.5000	$ 90,000,000
20	DDGS Price $/T	$103.57	$60-$200		$0.9321		0.3322	$ 19,930,634
21	CO2 Price ($ per Ton liq. CO2)	$6.00	$2- $12 / liq.Ton		$0.0540		0.0192	$ 1,154,618
22	MN Prod. Subsidy/gal.Denat. Ethanol	$0.00			$0.0000		0.0000	$ -
23	Federal Small Producer Subsidy							$ -
24	CCC Bioenergy Credit							$ -
25	Revenue per Unit				$5.1953		$1.8514	$ 111,085,252
26	Corn Price Paid by Processor ($ per bu.)	$3.00	$1.70---$5.00		$3.0000		$1.0691	$ 64,145,455
27	Gross Margin				$2.1953		$0.7823	$ 46,939,798
28					Cost /Bushel Ground		Cost /Gal. Denatured Sold	Plant Totals
29	Operating Expenses Per Bushel	Price per Unit						
30	Natural Gas Price ($ 1,000,000 Btu)	$9.00	$4.00-$14.00					
31	LP (Propane) Price ($ per gallon)	$1.10	$.55-$1.50 / gal.					
32	Factor of Time Operating on Propane	0.00	0-.12					
33	BTU's of Heat fr Fuel Req./ Denat. Gal.	34,000	28,500-40,000					
34	Combined Heating Cost				$0.8587		$0.3060	$ 18,360,000
35	Electricity Price ($ per kWh)	$0.08	$.025-$.12/kwh					
36	Kilowatt Hours Required per Denat.Gal.	0.750	0.5 - 1.25kwh					
37	Electrical Cost				$0.1578		$0.0563	$ 3,375,000
38	Total BTU's of Fuel and Electricity	41,500						
39	Total Energy Cost				$1.0165		$0.3623	$ 21,735,000
40		Cost/Denat. Gal. Ethanol						
41	Enzymes	$0.0480			$0.1347		$0.0480	$ 2,880,000
42	Yeasts	$0.0220			$0.0617		$0.0220	$ 1,320,000
43	Other Proc.Chemicals & Antibiotics	$0.0200			$0.0561		$0.0200	$ 1,200,000
44	Boiler & Cooling Tower Chemicals	$0.0050			$0.0140		$0.0050	$ 300,000
45	Water	$0.0060	$.005-.010		$0.0168		$0.0060	$ 360,000
46	Denaturant Price per Gal.	$1.1000	$0.80-$2.00		$0.0617		$0.0220	$ 1,320,000
47	Total Chemical Cost				$0.3452		$0.1230	$ 7,380,000
48								
49	Depreciation based on C49 asset life	15	Years		$0.3508		$0.1250	$ 7,500,000
50	Maintenance & Repairs	$0.0125			$0.0351		$0.0125	$ 750,000
51	Interest Expense				$0.1842		$0.0656	$ 3,937,500
52	Labor	$0.0292	$0.02 - $0.05		$0.0819		$0.0292	$ 1,752,000
53	Management & Quality Control	$0.0070	$0.005 - $0. 02		$0.0196		$0.0070	$ 420,000
54	Real Estate Taxes	$0.0020			$0.0056		$0.0020	$ 120,000
55	Licenses, Fees& Insurance	$0.0040	.0030-.0050		$0.0112		$0.0040	$ 240,000
56	Miscellaneous Expenses	$0.0135	$.01-$.03		$0.0379		$0.0135	$ 810,000
57	Total of Other Processing Costs				$0.7263		$0.2588	$ 15,529,500
58	Total Processing Costs				$2.0880		$0.7441	$ 44,644,500
59	Net Margin Achieved Per Unit				$0.1073		$0.0383	$ 2,295,298
60	Farmer-Investor Reqd. Return on Equity	12.00%			$0.3788		$0.1350	$ 8,100,000
61	Increment of Success/Failure to Meet Required Return				($0.2715)		($0.0967)	$ (5,804,702)
62								
63	Ethanol Plant Profits for Shareholders and Principal Reduction				$2,295,298		$2,295,298	$ 2,295,298

Figure 2. Ethanol Success Spreadsheet Base Case

and enter that in cell C11. The analysis assumes 2.75 gallons of anhydrous ethanol (2.81 gallons of denatured ethanol after adding 2 percent denaturant), 18 pounds of DDGS, and 18 pounds of CO2 are produced per bushel of corn. Historically, the price of DDGS has followed the price of corn, increasing and decreasing as corn prices move up and down. In this analysis, the price of DDGS is assumed to equal the price of corn ($0.0357/lb. or $71.43 per ton) when corn is $2.00 per bushel. It also assumes the price of DDGS increase 90 percent as much as the price of corn, providing an incentive for livestock producers to substitute the DDGS in livestock and poultry rations. For example, the price of DDGS with corn at $3.00 per bushel (the case shown in Figure 2) is $103.57 per ton. Notice that the plant is assumed to have a market for CO2 at $6.00 per ton.

The next section of the input column lists the assumptions to compute the operating expenses. Average Illinois natural gas prices and electricity prices for mid March, 2007 were used, $9.00 per million Btu, and $0.08 per Kwh. The plant is assumed to use 34,000 Btu of natural gas and 0.75 Kwh of electricity per gallon of denatured ethanol produced. Many plants have been successful in reducing the energy used for heat in the plant, cutting the natural gas requirement. And those plants that do not dry the distillers grains and solubles and sell the co-product feeds wet should save about 1/3 of the natural gas required. The typical cost of chemicals and water are listed in cells C41 through C46.

Depreciation is calculated using the straight-line method over 15 years. Thirty-five employees are assumed to be required to manage and operate the plant. The other overhead costs are listed in the final rows of the input column.

Consider the annual totals for the plant given in the final column of the spreadsheet. The plant sells 60 million gallons of ethanol at $1.50 per gallon for $90 million of revenue. Revenues from DDGS and CO2 are $19,930,634 and $1,154,618, respectively, making total revenues for the plant $111, 085,252 for the year. The largest expenditure the plant has is to purchase corn, $64,145,455. This is 59 percent of the plant's total cost for the year, $108,789,955 (I26 + I 58). The second largest expenditure is to purchase natural gas and electricity, $18,360,000, and $3,375,000, respectively, making energy 20.0 percent of total costs. The 35 employees receive $2,272,000, 2.1 percent of total costs. Notice in this example that the revenues are sufficient to pay all of the operating expenses listed and return $2,295,298 to equity capital, a 3.4 percent rate of return on the $67.5 million of equity capital. However, this is not large enough to provide the 12 percent rate of return on equity desired by the owners. That would have required a net margin of $8,100,000.

The net cost per gallon of ethanol after subtracting the revenue for sale of the co-products is given by the cost of corn (H 26) plus total processing costs (H 58) minus the value of the co-products sold per gallon (H20 + H21). In this example, with the price of corn at $3.00 per bushel, this is $1.0691 + 0.7441 – 0.3534 = $1.4598, or $1.46, for the 50 million gallon plant (Table 1). The cost of $1.46 per gallon includes a zero return to equity capital. Our investors indicated they want a 12 percent rate of return to equity, which would add $0.135 to the cost per gallon. They may include the 12 percent return to equity and indicate the cost to be 1.595 per gallon. In any event, under these assumptions it will take a price of approximately $1.60 per gallon to pay all costs and return a 12 percent rate of return to the equity capital.

The spreadsheet can be used to investigate the impact of changes in the assumptions on the cost of operating the plant and its profitability. For example, if the plant does not have a market for the CO2, the cost per gallon would increase $.0192 per gallon because the cost of capturing the CO2 is typically paid by the buyer of the CO2.

The price of corn has a major impact on the cost of producing ethanol. The net cost of ethanol increases $0.356 as the cost of corn increases $1.00 per bushel if the price of DDGS remains $71.43 per ton. However, the net increase in the cost per gallon is only $0.24 if the price of DDGS increases in proportion to the price of corn. The markets suggest the price of DDGS follows the corn price, but not in proportion. Thus, the net cost per gallon for alternative corn prices in Table 1 assumes the price of DDGS increase at 90 percent of the increase in the corn price. This results in a net increase of $0.2533 per gallon of ethanol for each $1 per bushel increase in the price of corn (Table 1).

Table 1: Cost of Ethanol Production for Alternative Corn Prices

Price Assumptions		Name Plate Capacity in Million Gal/Year	
Corn $/Bu.	DDGS $/ton	50	100
2.00	$71.43	$1.20	$1.15
3.00	103.57	1.46	1.40
4.00	135.71	1.71	1.65
5.00	167.85	1.96	1.91
6.00	199.99	2.22	2.16

The 100 million gallon plant, referred to as the larger plant in this section, has lower investment costs per gallon of capacity, $1.80 compared to $2.25 for the 50 million gallon per year plant. The analysis assumes the same percentage of equity, 60 percent, and debt, 40, as the smaller plant. Thus, owners of the smaller plant have $1.35 of equity capital per gallon, while owners of the 100 million gallon per year plant have only $1.08 per gallon of capacity. The smaller plant also has more borrowed capital per gallon than the larger plant, $0.90 compared to $0.72. The larger plant has one additional advantage in the cost computations presented here. It requires only 14 percent more labor to produce twice as much ethanol, 40 compared to 35 workers for the smaller plant. The other input and output requirements for the two plants are the same per gallon of capacity. The impact of these two factors is $.056 per gallon. The difference in depreciation and interest on the borrowed capital is $.038 per gallon, while the reduction in labor is $.018 per gallon. When a 12 percent return on equity capital is considered, it adds $0.108 to the cost figures in Table 1. This is $.027 less than the 12 percent return to equity for the smaller plant. Thus the larger plant has economies of scale of $.056 per gallon when a normal return to equity is not included and $.083 per gallon when a 12 percent rate of return is considered as part of the cost of the operation.

The larger plant may have some additional advantages in marketing and transportation cost, and in risk management that are not considered here. These costs are difficult to quantify and they have not been included. The estimates of economies of size presented are limited to the effects of lower investment and labor costs per gallon. While these data illustrate that there are definite cost advantages to larger size, the author emphasizes that there may be additional cost advantages to larger plant size that are not included in this analysis.

The cost per gallon is sensitive to many other factors. One of the more important is the price of the boiler fuel. This analysis assumes the plant uses 34,000 Btu per gallon of ethanol produced, and the impact of a $1 change in the price of natural gas is $0.034 per gallon of ethanol. Thus, the cost of ethanol with natural gas at $ 8 per million Btu instead of $9 is $0.034 less per gallon than the costs shown in Table1.

The Impact of Using Coal as the Boiler Fuel

The increase in the price of natural gas in recent years and the increasing variability of the natural gas price has stimulated interest in alternative boiler fuels for ethanol plants. In some cases the natural gas suppliers will only provide interruptible service, providing an additional reason for ethanol plants to consider an alternative fuel. In some locations, particularly where coal deposits are located within the state, coal is considered as the fuel of choice. This section presents estimates of the impact of using coal instead of natural gas on the cost per gallon of ethanol produced. The analysis is based on the updated construction costs provided earlier in this chapter and the work of Nicola that documents the additional inputs required for coal fired plants.

The estimates presented are for the same 50 million gallon nameplate capacity plant discussed earlier, but using a coal fired boiler instead of a natural gas fired boiler. Of course that requires some additional equipment and labor to handle the coal supply and to remove the ash. It requires more electricity to move coal and more Btu per gallon of ethanol, 37,000 compared to 34,000 for natural gas. It also requires some propane to start the boiler three times per year after it is shut down for maintenance. The offset is that coal is much less expensive per Btu. The analysis summarized here is based on the average composition of coal received and the average paid at other industrial plants in Illinois during July through September 2006 (DOE). The analysis is based on coal with 11,134 Btu per pound or 22, 268,000 Btu per ton, an ash content of 7.53 percent, and an average price of $36.93 per ton (DOE).

The analysis indicates the cost per gallon of ethanol with corn at $3.00 per bushel is $1.32 per gallon for a coal- fired plant compared to $1.46 for the natural gas fired plant (Table 1). However, this does not take account of the additional equity capital required for the coal fired plant. Providing a 12 percent rate of return to equity capital increases the cost of the coal fired plant to $1.497 per gallon, compared to $1.595 for the natural gas fired plant, a difference of $0.098 per gallon. This suggests the price of natural gas would have to be lowered to about $6.12 per million Btu to achieve the same cost per gallon as a coal-fired plant. Alternatively, with the natural gas price at $9.00 per million Btu, the coal-fired plant has approximately $5,880,000 to use annually for additional coal acquisition costs, meeting additional emission requirements, and adding to the bottom line.

The Impact of Alternative Ethanol and Corn Prices on Profitability

The ethanol industry has had some periods of relatively low and some periods of very favorable prices. Looking ahead both the price of the feedstock and the price of ethanol are very uncertain. Furthermore, the continuation of the federal excise tax exemption, which provides a payment of $0.51 per gallon of ethanol to the blender, is set to expire December 31, 2010. Efforts are being made to extend it, but continuation has its opponents. How might these uncertainties impact the profitability of our 50 million gallon natural gas fired ethanol plant?

The measure of profitability used in this analysis is the total annual return to equity capital. This includes the 12 percent return used in the previous analysis plus (minus) any additional returns (losses) earned per year under the price conditions analyzed.

Four price levels for ethanol were selected for this analysis to represent the wide range of outcomes that may unfold because of the uncertainties facing the industry at the current time. The highest price is based on an increase in the price of crude oil, while the remaining three are based on the DOE predicted refiner acquisition cost of about $60 per barrel. The four price levels should be thought of as the average annual netback price the plant receives for ethanol. This is the price in the market place minus the marketing and transportation cost of moving the ethanol from the plant to the market. The returns are annual returns to equity, so the price listed is the average annual netback price the plant receives.

- The highest netback ethanol price shown on Figure 3 is $2.30 per gallon. This might result from an increase in the price of crude oil to $75 per barrel, continuation of the blender's credit and continuation of a strong demand for ethanol as an octane enhancer. One can certainly think of cases that may result in higher ethanol prices, but the returns under this ethanol price are quite favorable and the reader can add $6 million dollars to each outcome in Figure 3 for each $0.10 increase in the ethanol netback price above $2.30 to analyze more favorable cases.

- The second netback ethanol price analyzed is $1.90 per gallon. This is the approximate netback price the plant might receive with crude oil at about $60 per barrel, continuation of the $0.51 blender's credit, and continued strong demand for ethanol for octane enhancement.

- The third netback ethanol price level, $1.50, is the price that may exist with oil at $60 per barrel, continuation of the blender's credit, but no premium paid for octane enhancement.

- Finally, the most pessimistic ethanol netback price, $1.10 per gallon, could result from $60 crude oil with revocation of the blender's credit and no premium paid for the octane enhancement of the fuel. In this case the ethanol would be purchased for its Btu content alone, making it worth about 2/3 of the wholesale price of gasoline less some transportation and marketing costs.

Figure 3: Annual Returns to Equity for 50 Million Gallon Dry-Mill

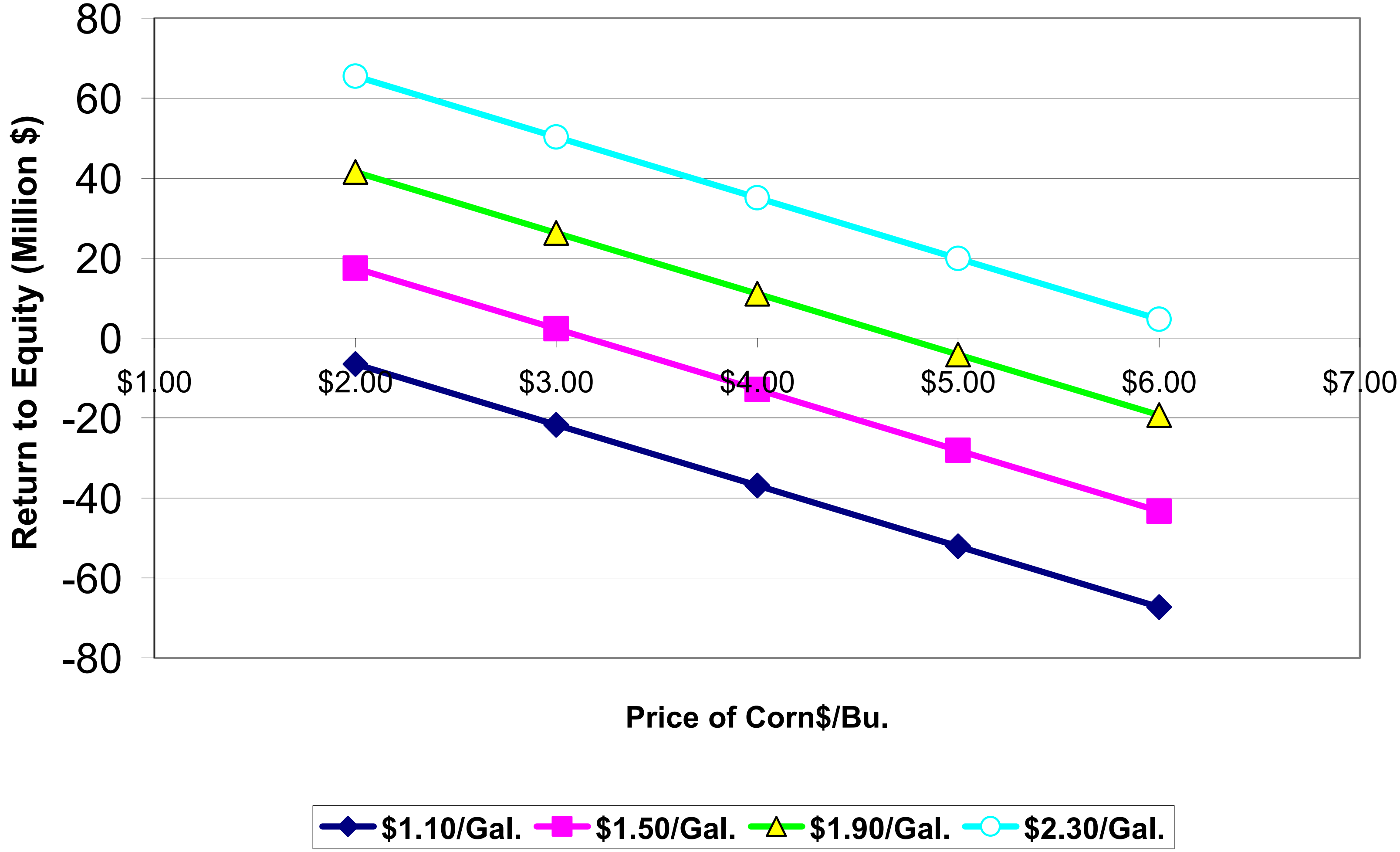

Figure 3 shows the annual return to equity capital on the vertical axis in millions of dollars and the price of corn per bushel on the horizontal axis. The impact of an increase in the corn price for a given netback price of ethanol can be traced by moving horizontally across the graph. For any netback price of ethanol, returns to equity decline $15,196.913 for each $1.00 increase in the price of corn. When the price of ethanol is $1.10, the plant has negative returns for all prices of corn above $1.57 per bushel. Of course the return increases as the price of ethanol increases, other things remaining constant. For this plant, selecting a given price of corn and increasing the netback price of ethanol $0.40 per gallon raises the annual return to the plant's equity holders $24 million.

The wide range of net returns to equity holders plotted on Figure 3 illustrates the importance of an effective risk management program to the profitability of an ethanol plant. Both corn and ethanol are commodities subject to wide and rapid changes in price level. Thus arrangements to purchase corn and natural gas, and to sell ethanol and DDGS under longer-term contracts are usually used to mitigate some of the price risk the plant faces.

A graph of the returns to equity for a 100 million gallon per year plant would have the same structure as Figure 3, but the dollar increments of annual gains or losses on the vertical axis would be approximately twice as large.

How much can a plant pay for corn?

The data used to construct Figure 3 can also be used to determine the price ethanol plants could pay for corn and earn a specified rate of return on their equity capital. For example, with an ethanol price of $1.90 per gallon, a 50 million gallon per year plant paying $4.74 per bushel for corn could pay all of its costs but would have a 0% rate of return on equity capital. This is the price of corn at which the $1.90 net profit line crosses the zero equity line in Figure 3. With a higher price of corn the plant would earn negative rates of return to equity capital. At lower prices of corn, the plant would earn positive rates of return to equity, as illustrated in Figure 3.

The prices of corn that would result in a zero return to equity, the breakeven prices, for the 50 million gallon per year ethanol plant for alternative ethanol prices are given in column 2 of Table 2. A corn price of $1.57 is the breakeven when ethanol is $1.10 per gallon. The breakeven increases to $3.16, $4.74, and $6.32 for ethanol prices of $1.50, $1.90 and $2.30 per gallon, respectively (Table 2). Notice that the corresponding price of DDGS is also shown in Table 2. As described earlier, the price of DDGS is assumed to be equal to the price of corn when corn is $2.00 per bushel. It is assumed to increase by 90% of the increase in the price of corn as corn price goes up.

The breakeven prices for the larger plant are shown in columns 4 and 5 of Table 2. Notice that the economies of size enjoyed by the larger plant enable it to pay $0.20 more per bushel of corn at each of the ethanol price levels.

Increasing the desired rate of return decreases the breakeven price of corn. For example, the data in Table 2 indicate the small plant can pay $.54 less at each price of ethanol to achieve a 12% rate of return than to achieve a 0% return. Notice, however, the breakeven price of corn for the large plant to achieve a 12% rate of return is only $0.32 more than for a zero rate of return.

The reason for the difference is that the larger plant has a smaller capital investment per gallon of ethanol.

Table 2. Breakeven Price of Corn for Alternative Ethanol Prices and Rates of Return to Equity

	0% Return to Equity				12% Return to Equity			
	50 mmgpy		100 mmgpy		50 mmgpy		100 mmgpy	
Ethanol $/Gal.	**Corn $/Bu.**	**DDGS $/Ton**	**Corn $/Bu.**	**DDGS $/Ton**	**Corn $/Bu.**	**DDGS $/Ton**	**Corn $/Bu.**	**DDGS $/ton**
1.10	1.57	57.61	1.77	64.04	1.03	40.25	1.35	49.80
1.50	3.16	108.72	3.36	115.14	2.62	91.36	2.94	101.64
1.90	4.74	159.51	4.94	165.93	4.20	142.14	4.52	152.43
2.30	6.32	210.29	6.52	216.70	5.78	192.93	6.10	203.21

Closing Comments

Site selection is an important aspect of developing a profitable ethanol production facility. The discussion in this chapter emphasized the importance of location on the cost of corn, fuel and transportation. In addition to the impact of location on costs, those selecting a site should not overlook differences in marketing opportunities from one location to another, such as the opportunity to sell wet distillers grains and access to a buyer for CO2. One must balance the additional revenues with the differences in cost.

Using a tool like the ethanol success spreadsheet to compare alternative locations and configurations of a plant is usually time well spent during the initial planning stages. Of course more detailed planning and development of a business plan with more specific data for the site and local conditions will be required before moving ahead. The spreadsheet and analyses suggested in this chapter are not intended to replace a more thorough analysis.

Economies of size are very important in annual profitability and the long-run survivability of an ethanol plant. A cost reduction of $.01 per gallon will increase annual profits $1.2 million for a plant producing 120 million gallons per year. Thus the effect of lower investment and operating costs associated with larger plants are very important to long-run profitability.

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