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Preliminary Cost Estimates - Producing Alcohol Fuel From a Small Scale Plant

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PRELIMINARY COST ESTIMATES—

PRODUCING ALCOHOL FUEL FROM A SMALL SCALE PLANT

Warning:

Read the cautions page 2

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Caution

Preliminary cost estimates for producing fuel alcohol in a small plant are reported in this paper. Data for the analysis came in part from operation of the South Dakota State University (SDSU) fuel alcohol plant and in part from other sources noted in the annexes.

Since the SDSU alcohol plant is an experimental research facility, you must be cautious about drawing conclusions from this cost analysis. Wherever possible, costs were estimated as if plant construction and operation were on a commercial basis.

However, a major warning to keep in mind--spelled out in the paper--is that some parts of the SDSU plant were not capable of being fully utilized during the study period because of limited cooking and fermentation capacity. This caused heavy fixed costs to be associated with rather limited potential annual output, resulting in high per unit costs.

Modifications in the plant will bring potential production closer to the distillation capacity, consequently lowering per unit costs. Future analyses will determine costs of production for plant designs that more closely approximate commercial conditions.

In spite of these limitations, the cost breakdowns and associated annex discussions in this paper provide a useful starting point. Potential alcohol fuel investors can examine these and other available cost estimates to determine the figures that come closest to their own individual situations.

This report would not have been possible without excellent cooperation from other members of the SDSU Alcohol Fuels Research Team. Especially helpful during this first stage of analysis were Mr. Scott Stampe of the Agricultural Engineering Department and Mr. Paul Whalen of the Microbiology Department. Various other individuals in the Economics, Microbiology, Agricultural Engineering, Mechanical Engineering, Animal Science, and Dairy Science departments provided advice and reviewed drafts of this paper. Their cooperation is appreciated.

PRELIMINARY COST ESTIMATES—
PRODUCING ALCOHOL FUEL FROM A SMALL SCALE PLANT

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This paper provides an interim progress report on research at South Dakota State University (SDSU) concerning the economics of producing fuel alcohol in "small-scale" plants.

Estimated per gallon costs of producing alcohol are quite high.

The lowest estimate is $3.12 per gallon of alcohol (based upon $2.00 corn, a 10% interest rate, and 9,088 gal per year production). The highest estimate is $5.70 per gallon (based upon $2.34 corn, a 15% interest rate, and 4,544 gal per year annual production).

These costs indicate the need for utilizing all capital components of a plant close to their capacities, reducing fixed costs per unit of alcohol output.

It is obvious that a commercial plant of this general type and size must be designed to produce much more than would have been possible with the SDSU research plant. Because of limited cooking and fermentation capacity, the distillation unit of the SDSU plant could not have been used anywhere near its physical capacity during the period covered by this report. This means that the high fixed costs for a building, distillation equipment, and a centrifuge were associated with a fairly low annual output capacity.

Investment in additional cooking and fermentation capacity, along with some additional investment in other facilities (e.g., grain handling equipment) could substantially increase the capacity of the basic plant analyzed in this report. Some such expansions in the SDSU plant are now underway; others will be made in the future; and still others could be made if the plant were to be fully modeled on a commercial basis.

Just how much additional capital investment would be required to make a plant such as that at SDSU more economically practical, and how much per unit alcohol costs could thereby be lowered, is the subject of future analysis. Very preliminary estimates indicate that designing the SDSU plant for capacity utilization of the distillation columns would increase the initial investment from $90,600 to slightly more than $130,000.

With this additional investment of around $40,000, annual alcohol production of close to 160,000 gal might be possible under ideal operating conditions. This could, at least theoretically, lower net costs per gallon to around $1.50 to $1.75.

More experimental work needs to be done, however, before the practical feasibility of a greatly expanded "small-scale" plant is known and hard estimates of the cost of production for an expanded plant can be made.[1/]

Potential investors in fuel alcohol production facilities should review all

[1/] A recent analysis at the University of Nebraska indicated that per gallon alcohol production costs might be lowered from $4.58 to $2.44 by increasing initial plant investment outlays from $73,500 to $104,000, thereby increasing annual output capacity from 6,000 gal to 40,000 gal. See Loyd K. Fischer, "The economics of fuel alcohol in farm size plants." Proceedings: Alcohol Fuel Workshop. Great Plains Agricultural Council Publication No. 94. Manhattan, Kansas: Kansas State University, May 13-14, 1980.

available cost and return information and make estimates pertaining to their own particular situations. Several key factors need to be examined in making alcohol fuel investment decisions. These factors include the following:[2/]

(1) Are required inputs available at reasonable cost? In addition to the basic feedstock (e.g., corn), this includes such items as labor.

(2) Can the fuel alcohol be utilized on local farms or be marketed?

(3) How well can the feed byproduct be utilized?

(4) What kind of financing can be arranged?

(5) Taking all of the above into consideration, what will be the net cost of producing ethanol for fuel?

Data in this report are based in part on SDSU's experimental plant--as it existed and operated during the 1979-80 academic year (through May 1980). Modifications have since been made which are not reflected in this initial progress report. Stainless steel distillation columns were substituted for mild steel columns in the late spring of 1980. This is reflected in the following cost data, however.

Sources other than the SDSU plant were also used in the cost analysis. In many cases, very rough estimates have been made. (The sources and bases for assumptions are cited in annexes to the paper.)

Cost estimates can be substantially refined as more experience is gained and additional physical and biological data are produced in experiments at SDSU and elsewhere. The findings reported in this paper should be considered only as first approximations.

Keep the following point in mind. The experimental plant at SDSU was capable of producing only around 9,000 gal of fuel alcohol annually during the 1979-80 academic year. It would cost around $90,000 to reproduce this plant (including auxiliary facilities) on a private, commercial basis. These high capital costs, combined with the relatively low potential annual output, result in extremely high estimated costs per gallon of fuel alcohol. However, additional fermentation capacity, which could be added at a modest cost, could enable significantly greater quantities of alcohol to be produced annually.

Additional fermentation capacity is now being added to the SDSU plant. This will bring fixed (and, hence, total) costs per unit of alcohol down substantially. Therefore, analyses over the coming year at SDSU will examine the economics of an expanded plant.

Tables 1 and 2 are based on the assumption that one batch of corn (39 bu) per week is processed for alcohol production. Each 960-gal fermentation batch results in about 93 gal of 190 proof fuel alcohol. Assuming 49 weeks per year of operation, potential annual output from one batch per week is 4,544 gal.

Two batches per week are assumed in Tables 3 and 4. This results in weekly output of approximately 185 gal and potential annual output (at 49 weeks per year of production) of 9,088 gal of fuel.

The discussion in this paper is based on the following budgeting assumptions:

[2/] These factors are discussed in Thomas L. Dobbs, "Should I get involved in fuel alcohol production? Economic considerations." EMC 837, SDSU Cooperative Extension Service, June 1980.

(1) cost of corn is $2.34 per bushel (the 1980 estimated cost of producing corn in southeastern South Dakota, including a charge for or return to land). The corn cost assumption is varied in one section of this paper.

(2) annual fuel alcohol production is either 4,544 gal (Tables 1 and 2) or 9,088 gal (Tables 3 and 4).

(3) interest rate for amortizing capital costs and charging for operating costs is 10%. This rate is reflected in Tables 1 and 3. An alternative rate of 15% is used in Tables 2 and 4.

Capital Costs

Estimates for capital costs (see tables) are based on replacement costs for equipment similar to or serving the same function as the equipment being used in the first phase of work under the SDSU Alcohol Fuels Research Project. Various useful lives are assumed. New purchase costs are assumed; if an investor has some components already available (e.g., a building) or can fabricate some components himself, certain costs could be lower.

Total capital costs are $89,105 in Table 1 and $90,600 in Table 3. The totals differ because the grain storage charge in Table 1 is only half of that in Table 3. Capital costs per gallon of alcohol produced are $2.70 in Table 1 and $1.40 in Table 3.

All of the metal equipment, except the distillation columns, is plain steel. Experience at SDSU indicates that stainless steel columns will probably be necessary to avoid severe corrosion problems, thus extending the useful lives of the columns. The use of plain steel equipment reduces the initial investment cost but shortens the plant's expected useful life.

For a more detailed explanation of the plant's capital costs, see Annex A.

Other Fixed Costs

Insurance, maintenance, and property tax costs included in "other fixed costs" are $3,432 in Table 1 and $4,390 in Table 3. Other fixed costs <u>per gallon of alcohol produced</u> total $0.76 in Table 1 and $0.49 in Table 3.

For an explanation of "other fixed costs," refer to Annex B.

Operating Costs

A batch cook and fermentation process was incorporated with a potentially continuous distillation process. In Table 1, it is assumed that one 960-gal fermentation batch is distilled per week, and in Table 3, it is assumed that two of these batches are distilled per week. The plant is assumed to run 49 weeks per year in both tables.

The ingredients and outputs assumed in the analysis for each batch are listed below:

(1) <u>Corn input</u>: 38.67 bu, or 2,165.52 lb.

(2) <u>Water input</u>: 812.07 gal, or 6,764.54 lb.

(3) <u>Alcohol output (including denaturant)</u>: 92.736 gal.

(4) <u>Feed byproduct output</u>: 1.03 ton at 70% moisture (after passing through centrifuge).

Quantities are doubled in the two-batch per week analyses.

Operating costs per year total $8,176 in Table 1 and $15,881 in Table 3. Operating costs per gallon of alcohol produced are $1.82 in Table 1 and $1.76 in Table 3.

An explanation of the major assumptions and bases used in determining operating costs is included in Annex C.

Total Costs

Total annual cost of producing alcohol is $23,872 in Table 1 and $32,710 in Table 3. Total per gallon cost is $5.28 in Table 1 and $3.65 in Table 3. These costs do not reflect a credit for the feed byproduct.

Credit for Byproduct

Each 960-gal fermentation batch yields approximately 1.03 ton (after centrifuging) of a 70% moisture/10% protein feed byproduct, currently valued at $34 per ton. For an explanation of the byproduct quantity and value estimates, see Annex E.

The lower level of production yielded 50.5 ton of feed byproduct per year (Table 1), resulting in an annual credit to production costs of $1,717 or a per gallon credit of $0.38.

Feed byproduct yielded in the two-batch per week case (Table 3) is 101 ton per year. This creates an annual credit to production costs of $3,434 or a per gallon credit of $0.38.

Net Cost

Deducting byproduct credits leaves an annual cost of $22,155 or $4.90 per gallon when alcohol is produced on a one-batch per week basis (Table 1). Under a two-batch per week operation, byproduct credit is $29,276 annually or $3.27 per gallon of alcohol (Table 3).

Sensitivity Analyses

The cost of producing alcohol from corn in this assumed small-scale plant ranges from $3.27 per gallon (Table 3) to $4.90 per gallon (Table 1), depending on whether one or two batches of corn is processed per week. That analysis is based on assumptions of $2.34 corn and 10% annual interest rates.

Alternative corn price and interest rate assumptions were also used to test the sensitivity of alcohol cost results to these two variables.

If the price of corn drops from $2.34 per bushel to $2.00 per bushel, the net cost of producing alcohol drops by $0.15 per gallon. Increasing the price of corn from $2.34 to $2.50 per bushel increases the net cost by $0.06 per gallon.[3/]

Alternately stated, if a plant yields 2.4 gal of alcohol for every bushel of corn used in the production process, a $0.50 per bushel change in the price of corn results in a $0.21 per gallon difference in production costs. (These results are summarized in Table 5.)

Changing the interest rate assumption has a major effect on annual capital costs and a relatively minor effect on per gallon operating costs. Compare Table 1 with 2 or Table 3 with 4.

Comparison of Tables 3 and 4 shows that an increase in the interest rate from 10% to 15% raises the annual (amortized) cost[4/] of capital (for a plant costing $90,600) from $12,438 to $16,008. The per gallon capital cost increases from $1.40 to $1.79, assuming an annual production level of 9,088 gal.

A change in the interest rate will also have an effect on operating costs, through the "interest on operating capital" item. If the annual interest rate were to increase from 10% to 15%, the interest on operating capital would increase from $387 to $581 annually or from 4¢ to 6¢ per gallon (compare Tables 3 and 4).

The combined effects on capital and operating costs of a change in the annual interest rate from 10% to 15% is 41¢ per gallon, assuming the two-batch per week operation. In effect, a one percentage point change in the interest rate changes alcohol costs by approximately 8¢ per gallon.

[3/] In addition to the effect on feedstock cost, there is a minor effect on the "interest on operating capital" item. This effect is very small, however.

[4/] Amortized costs include, in effect, both depreciation and interest charges.

TABLES
ANNEXES

Table 1. Fuel alcohol production costs: 4,544 gallons per year, 10% interest rate, $2.34 corn.

Brief description: (1) water input = 812.07 gal/wk, 49 wk/yr, for total of 39,791.43 gal/yr; (2) corn input = 38.67 bu/wk or 1,894.83 bu/yr; (3) alcohol output (190 proof) = 92.736 gal/wk or 4,544 gal/yr; and (4) feed byproduct output = 1.03 ton/wk or 50.5 ton/yr.

I. Capital costs

Item	Capital cost	Useful life (years)	Annual cost (amortized at 10%)	Cost per gallon
Grain storage	$ 1,495	20	$ 175.60	$ .04
Steam boiler	7,000	15	920.32	.20
Fermentation tank	2,750	10	447.55	.10
Cook tank	2,650	10	431.28	.10
Distillation columns	18,500	10	3,010.79	.66
Temperature meter	300	10	48.82	.01
Gauges	195	10	31.74	.01
Boiler fuel tank	1,224	10	199.20	.04
Alcohol storage	365	10	59.40	.01
Pumps & motors	2,526	10	411.10	.09
Pipes	100	5	26.38	.01
Centrifuge	28,000	15	3,681.26	.81
Building	24,000	20	2,819.03	.62
Subtotals	$ 89,105		$12,262.47	$ 2.70

II. Other fixed costs

Item	Annual cost	Cost per gallon
Insurance	$ 347.00	$ .08
Maintenance	1,782.10	.39
Property taxes	1,303.61	.29
Subtotals =	$ 3,432.71	$ .76

(Table 1, continued)

III. Operating costs

Item	Cost per unit	Units per 960 gal mash	Total cost per batch	Annual cost	Cost per gallon
Corn	$2.34/bu	38.67 bu	$ 90.49	$4,434.50	$ .98
Corn grinding	$6/100 bu	38.67 % of 100	2.32	113.68	.03
Diazyme L-100	$2.62/liter	1.47 liter	3.85	188.65	.04
Taka-therm	$1.30/lb	450 ml	1.55	75.95	.02
Sulfuric acid	$1.17/gal	.71 gal	.83	40.67	.01
Yeast	$.90/lb	1 lb	.90	44.10	.01
Electricity	$0.28/kwh	66.957 kwh	1.87	91.63	.02
Fuel (propane)	$.565/gal	34.419 gal	19.45	953.05	.21
Water	$1.25/1000 gal	812.07 gal	1.02	49.98	.01
Water treatment	---	---	3.21	157.50	.04
Denaturant	$1.20/gal	4.416 gal	5.30	259.70	.06
Labor	$4/hr	8 hr	32.00	1,568.00	.35
Interest on operating capital (10% annually, avg of 3 mo/yr)			4.07	199.43	.04
Subtotals =			$ 166.86	$8,176.84	$ 1.82

	Annual cost	Cost per gallon
IV. Total of I, II, and III =	$23,872.02	$5.28
V. Credit for byproduct (at $34/ton)	-1,717.00	-.38
VI. Net cost of 190 proof alcohol =	$22,155.02	$4.90

Table 2. Fuel alcohol production costs: 4,544 gallons per year, 15% interest rate, $2.34 corn.

Brief description: (1) water input = 812.07 gal/wk, 49 wk/yr, for total of 39,791.43 gal/yr; (2) corn input = 38.67 bu/wk or 1,894.83 bu/yr; (3) alcohol output (190 proof) = 92.736 gal/wk or 4,544 gal/yr; and (4) feed by-product output = 1.03 ton/wk or 50.5 ton/yr.

I. Capital costs

Item	Capital cost	Useful life (years)	Annual cost (amortized at 15%)	Cost per gallon
Grain storage	$ 1,495	20	$ 238.85	$ .05
Steam boiler	7,000	15	1,197.12	.26
Fermentation tank	2,750	10	547.94	.12
Cook tank	2,650	10	528.02	.12
Distillation columns	18,500	10	3,686.16	.81
Temperature meter	300	10	59.78	.01
Gauges	195	10	38.85	.01
Boiler fuel tank	1,224	10	243.88	.05
Alcohol storage	365	10	72.73	.02
Pumps & motors	2,526	10	503.31	.11
Pipes	100	5	29.83	.01
Centrifuge	28,000	15	4,788.48	1.05
Building	24,000	20	3,834.27	.85
Subtotals	$ 89,105		$15,769.22	$3.47

II. Other fixed costs

Item	Annual cost	Cost per gallon
Insurance	$ 347.00	$ .08
Maintenance	1,782.10	.39
Property taxes	1,303.61	.29
Subtotals =	$3,432.71	$ .76

(Table 2, continued)

III. Operating costs

Item	Cost per unit	Units per 960 gal mash	Total cost per batch	Annual cost	Cost per gallon
Corn	$2.34/bu	38.67 bu	$ 90.49	$4,434.50	$ .98
Corn grinding	$6/100 bu	38.67 % of 100	2.32	113.68	.03
Diazyme L-100	$2.62/liter	1.47 liter	3.85	188.65	.04
Taka-therm	$1.30/lb	450 ml	1.55	75.95	.02
Sulfuric acid	$1.17/gal	.71 gal	.83	40.67	.01
Yeast	$.90/lb	1 lb	.90	44.10	.01
Electricity	$.028/kwh	66.957 kwh	1.87	91.63	.02
Fuel (propane)	$.565/gal	34.419 gal	19.45	953.05	.21
Water	$1.25/1000 gal	812.07 gal	1.02	49.98	.01
Water treatment	---	---	3.21	157.50	.04
Denaturant	$1.20/gal	4.416 gal	5.30	259.70	.06
Labor	$4/hr	8 hr	32.00	1,568.00	.35
Interest on operating capital (15% annually, avg of 3 mo/yr)			6.10	299.13	.07
Subtotals =			$ 168.89	$8,276.54	$ 1.85

		Annual cost	Cost per gallon
IV.	Total of I, II, and III =	$27,478.47	$6.08
V.	Credit for byproduct (at $34/ton)	-1,717.00	-.38
VI.	Net cost of 190 proof alcohol =	$25,761.47	$5.70

Table 3. Fuel alcohol production costs: 9,088 gallons per year, 10% interest rate, $2.34 corn.

Brief description: (1) water input = 1,624.14 gal/wk, 49 wk/yr, for total of 79,582.86 gal/yr; (2) corn input = 77.34 bu/wk or 3,789.66 bu/yr; (3) alcohol output (190 proof) = 185.472 gal/wk or 9,088 gal/yr; and (4) feed byproduct output = 2.06 ton/wk or 101 ton/yr.

I. Capital costs

Item	Capital cost	Useful life (years)	Annual cost (amortized at 10%)	Cost per gallon
Grain storage	$ 2,990	20	$ 351.60	$ .04
Steam boiler	7,000	15	920.32	.10
Fermentation tank	2,750	10	447.55	.05
Cook tank	2,650	10	431.28	.05
Distillation columns	18,500	10	3,010.79	.33
Temperature meter	300	10	48.82	.01
Gauges	195	10	31.74	.01
Boiler fuel tank	1,224	10	199.20	.02
Alcohol storage	365	10	59.40	.01
Pumps & motors	2,526	10	411.10	.05
Pipes	100	5	26.38	.01
Centrifuge	28,000	15	3,681.26	.41
Building	24,000	20	2,819.03	.31
Subtotals	$ 90,600		$12,438.07	$ 1.40

II. Other fixed costs

Item	Annual cost	Cost per gallon
Insurance	$ 347.00	$ .04
Maintenance	2,718.00	.30
Property taxes	1,325.48	.15
Subtotals =	$4,390.48	$ .49

(Table 3, continued)

III. Operating costs

Item	Costs per unit	Units per 1,920 gal mash	Total cost per batch	Annual cost	Cost per gallon
Corn	$2.34/bu	77.34 bu	$ 180.98	$ 8,868.02	$ .98
Corn grinding	$6/100 bu	77.34% of 100	4.64	227.36	.03
Diazyme L-100	$2.62/liter	2.94 liter	7.70	377.30	.04
Taka-therm	$1.30/lb	900 ml	3.10	151.90	.02
Sulfuric acid	$1.17/gal	1.42 gal	1.66	81.34	.01
Yeast	$.90/lb	2 lbs	1.80	88.20	.01
Electricity	$.028/kwh	133.19 kwh	3.73	182.77	.02
Fuel (propane)	$.565/gal	68.838 gal	38.89	1,905.61	.21
Water	$1.25/1000 gal	1624.14 gal	2.03	99.47	.01
Water treatment	---	---	5.08	248.75	.03
Denaturant	$1.20/gal	8.832 gal	10.60	519.40	.06
Labor	$4/hr	14 hr	56.00	2,744.00	.30
Interest on operating capital (10% annually, avg of 3 mo/yr)			7.91	387.59	.04
Subtotals =			$ 324.12	$15,881.71	$ 1.76

	Annual cost	Cost per gallon
IV. Total of I, II, and III =	$32,710.26	$3.65
V. Credit for byproduct (at $34/ton)	-3,434.00	-.38
VI. Net cost of 190 proof alcohol =	$29,276.26	$3.27

Table 4. Fuel alcohol production costs: 9,088 gallons per year, 15% interest rate, $2.34 corn.

Brief description: (1) water input = 1,624.14 gal/wk, 49 wk/yr, for total of 79,582.86 gal/yr; (2) corn input = 77.34 bu/wk or 3,789.66 bu/yr; (3) alcohol output (190 proof) = 185.472 gal/wk or 9,088 gal/yr; and (4) feed byproduct output = 2.06 ton/wk or 101 ton/yr.

I. Capital costs

Item	Capital cost	Useful life (years)	Annual cost (amortized at 15%)	Cost per gallon
Grain storage	$ 2,990	20	$ 477.69	$ .05
Steam boiler	7,000	15	1,197.12	.13
Fermentation tank	2,750	10	547.94	.06
Cook tank	2,650	10	528.02	.06
Distillation columns	18,500	10	3,686.16	.41
Temperature meter	300	10	59.78	.01
Gauges	195	10	38.85	.01
Boiler fuel tank	1,224	10	243.88	.03
Alcohol storage	365	10	72.73	.01
Pumps & motors	2,526	10	503.31	.06
Pipes	100	5	29.83	.01
Centrifuge	28,000	15	4,788.48	.53
Building	24,000	20	3,834.27	.42
Subtotals	$ 90,600		$16,008.06	$1.79

II. Other fixed costs

Item	Annual cost	Cost per gallon
Insurance	$ 347.00	$ .04
Maintenance	2,718.00	.30
Property taxes	1,325.48	.15
Subtotals =	$4,390.48	$ .49

(Table 4, continued)

III. Operating costs

Item	Costs per unit	Units per 1,920 gal mash	Total cost per week	Annual cost	Cost per gallon
Corn	$2.34/bu	77.34 bu	$ 180.98	$ 8,868.02	$ .98
Corn grinding	$6/100 bu	77.34% of 100	4.64	227.36	.03
Diazyme L-100	$2.62/liter	2.94 liter	7.70	377.30	.04
Taka-therm	$1.30/lb	900 ml	3.10	151.90	.02
Sulfuric acid	$1.17/gal	1.42 gal	1.66	81.34	.01
Yeast	$.90/lb	2 lb	1.80	88.20	.01
Electricity	$.028/kwh	133.19 kwh	3.73	182.77	.02
Fuel (propane)	$.565/gal	68.838 gal	38.89	1,905.61	.21
Water	$1.25/1000 gal	1624.14 gal	2.03	99.47	.01
Water treatment	---	---	5.08	248.75	.03
Denaturant	$1.20/gal	8.832 gal	10.60	519.40	.06
Labor	$4/hr	14 hr	56.00	2,744.00	.30
Interest on operating capital (15% annually, avg of 3 mo/yr)			11.86	581.14	.06
Subtotals =			$ 328.07	$ 16,075.26	$ 1.78

		Annual cost	Cost per gallon
IV.	Total of I, II, and III =	$36,473.80	$4.06
V.	Credit for byproduct (at $34/ton)	-3,434.00	-.38
VI.	Net cost of 190 proof alcohol =	$33,039.80	$3.68

Table 5. Effects of changes in corn price on alcohol production costs*

Cost items	Costs/gallon of alcohol at different corn prices		
	$2/bu	$2.34/bu	$2.50/bu
(A) <u>Plant operating at one batch per week</u>			
1. Corn cost	.83	.98	1.04
2. Total (net) cost	4.75	4.90	4.96
(B) <u>Plant operating at two batches per week</u>			
1. Corn cost	.83	.98	1.04
2. Total (net) cost	3.12	3.27	3.33

*Based upon budgets using 10% interest rates.

ANNEX A

Explanation of capital cost estimates

(1) Grain storage: from Opland Agri-service, Brookings, SD, for a 5,000-bu capacity grain bin. Only half of the bin's cost is charged to alcohol production in Tables 1 and 2, since 5,000 bu of capacity are more than what is required. The bin's total cost is charged to alcohol production in Tables 3 and 4.

(2) Steam boiler: from Energy Control Engineering, Elk River, Minnesota, for a 20-hp, low utility steam boiler.

(3) Fermentation tank: from Fabricators Incorporated, Sioux City, Iowa, for a 1,000-gal, 10-gauge plain steel fermentation tank with coils.

(4) Cook tank: from a bid submitted by Fabricators Incorporated, Sioux City, Iowa, for a plain steel tank.

(5) Distillation columns: from Arlon Industries Incorporated, Sheldon, Iowa, for 12-inch diameter, stainless steel, insulated columns with a 20-25 gal per hour distillation capacity.

(6) Temperature meter: based on a conversation with Mr. Spencer Kittelson, builder of the SDSU plant's temperature readouts.

(7) Gauges: from a verbal estimate by Mr. Scott Stampe, Agricultural Engineering, SDSU Alcohol Fuels Research Team, for three flow gauges.

(8) Boiler fuel tank: from the Farmers Cooperative Company, Brookings, SD, for a 1,000-gal liquid propane tank.

(9) Alcohol storage: from Community Oil Company, Brookings, SD, for a 1,000-gal plain steel storage tank and fittings.

(10) Pumps and motors: from (1) Roper Pump Company, Commerce, Georgia, for two progressive cavity pumps; (2) Viking Pump Division, Cedar Falls, Iowa, for two reflux pumps; (3) Shakstad's, Sioux Falls, SD, for four 1/2-hp electric motors; and (4) Syl's Auto Electric, Brookings, SD, for two 2-hp electric motors.

(11) Pipes: based on the fact that the SDSU plant uses one-inch rubber hose at $1 a foot.

(12) Centrifuge: based on a verbal cost estimate by Mr. Paul Whalen, Microbiology Department, SDSU Alcohol Fuels Research Team, for the centrifuge used at the SDSU alcohol plant.

(13) Building: based on information from an SDSU extension specialist for a 30' x 40' insulated shed with a concrete floor, at $20 per square foot.

ANNEX B

Explanation of other fixed cost estimates

(1) Insurance: taken from Small-scale fuel alcohol production, USDA, March 1980. It was estimated as a flat amount. Actual cost will vary from state to state and insurer to insurer.

(2) Maintenance: based on 2% of the total cost of capital in Tables 1 and 2 and 3% of the total cost of capital in Tables 3 and 4. The maintenance cost was increased from 2% in Tables 1 and 2 to 3% in Tables 3 and 4 because the plant is utilized more heavily in the latter instance. Small-scale fuel alcohol production, USDA, March 1980, contains estimated maintenance costs of 4% of the total cost of capital.

(3) Property taxes: Property tax information is from the Brookings County Director of Assessment. The tax rate applied is for a permanent site in Brookings County.

Note: South Dakota does offer a tax assessment credit for the installation of renewable energy systems, including ethyl alcohol production facilities (for both private and commercial plants). However, a property tax charge was included in this paper to illustrate that property taxes need to be considered for at least part of the investment life by a potential alcohol producer. Private plants qualify for a 100% credit and commercial plants for a 50% credit. The credit may be applied for 3 continuous years, followed by 3 years of diminishing credit of 75%, 50%, and 25%.

ANNEX C

Explanation of operating costs estimates

Major assumptions and bases used in determining operating costs:

(1) The cost of corn assumes the use of total costs--including land charges--for southeastern South Dakota. This is Area 6, including Moody, Minnehaha, Turner, Lincoln, Yankton, Clay, and Union counties.

(2) Corn grinding cost assumes alcohol producer rents a corn grinder and grinds the corn himself. Labor for this operation is included in the labor requirement estimates made elsewhere.

(3) Corn, water, Diazyme, Taka-therm, sulfuric acid, yeast, electricity, and fuel requirements are based on estimates from "Alcohol production energy analysis," by Scott Stampe, SDSU Alcohol Fuels Research Team, February 1980. Presently (fall 1980), the yeast used for fermentation is being produced in the laboratory rather than supplied commercially. Future cost analyses based upon this practice may therefore show somewhat different yeast costs.

(4) Electrical rates are from Sioux Valley Electric, Colman, SD. We assume that the alcohol producer is a farmer who already uses over 1,500 kwh.

(5) Propane fuel is assumed to be used to run the steam boiler.

(6) Water cost estimates assume the use of rural water at rates for Brookings County and that the producer already uses 22,000 gal of water per month.

(7) A water treatment cost is included in order to avoid scale problems in the steam boiler and contamination problems in the mash. Costs include a monthly rental charge for the unit and a charge for the cost of salt. In Tables 1 and 2, the water conditioning unit is a 24,000-grain unit which uses 6 lb of salt per day at $0.05 per lb and has a monthly rental charge of $7. In Tables 3 and 4, the water conditioning unit is a 45,000-grain unit which uses 11 lb of salt per day and has a monthly rental charge of $9.50.

(8) Denaturant cost assumes the use of the new denaturing formula #20: To every 100 gal of ethyl alcohol of not less than 160 proof, add 5 gal of gasoline.

(9) Labor requirement per gallon of alcohol is assumed to be .09 hr per gal of alcohol produced in Tables 1 and 2 and .075 hr per gal of alcohol produced in Tables 3 and 4. The labor requirement in Tables 3 and 4 is slightly less per gallon than in Tables 1 and 2, due to assumed increased efficiency of production. These estimates are slightly higher than the .05 hr per gal estimated in the USDA publication <u>Small-scale fuel alcohol production</u> for a plant of similar size. If annual output were increased substantially above 9,000 gal per year, actual per unit labor requirements might be closer to the USDA estimate. On the other hand, technical skills and management required for quality control could raise labor costs above those estimated in this paper.

ANNEX D

Explanation of alcohol production estimates

Alcohol production input-output relationships were estimated on the basis of information from "Alcohol production energy analysis," by Scott Stampe, SDSU Alcohol Fuels Research Team, February 1980 and information received verbally from members of the SDSU Alcohol Fuels Research Team. More accurate estimates of alcohol production coefficients will be possible as additional data from plant runs are generated at SDSU.

Since the cooking is done in batches of 320 gal, the following calculations are for one 320-gal cook batch. There are three of these cook batches in each 960-gal fermentation batch that is distilled.

Calculations:

(1) Mash is mixed by combining 12.89 bu (721.84 lb) of corn and approximately 271 gal of water in the cook tank. This mixture is heated with steam and cooked to convert starch to sugar via an enzyme process.

(2) Next, the mash is fermented to convert the sugars to alcohol. A concentration of 10% alcohol is sought at the SDSU Alcohol Fuels Research plant. Thus, each 320-gal cook batch contains approximately 32 gal of alcohol after fermentation. (Note: this is the alcohol content of the mash, not the alcohol yield.)

(3) According to information received verbally from members of the SDSU Alcohol Fuels Research Team, 92% of the alcohol content, or 29.44 gal of alcohol per 320-gal cook batch, is distilled out by the columns as 190 proof ethyl alcohol.

(4) There are three of these 320-gal cook batches in every 960-gal fermentation batch distilled, so we simply multiply 29.44 times 3 to get an alcohol production estimate of 88.32 gal per 960-gal fermentation batch.

(5) The alcohol is denatured by adding 4.416 gal of denaturant per 88.32 gal of alcohol; the final output per 960-gal fermentation batch is 92.736 gal.

ANNEX E

Explanation of by-product quantity and value estimates

(1) Quantity

(a) According to an SDSU Extension Agricultural Engineer, about 25 gal of 92% moisture stillage, containing about 17 lb of solids, are yielded per bushel of corn utilized in the production process.

(b) Each fermentation batch contains 38.67 bu of corn. Thus, there will be 966.75 gal (38.67 x 25 = 966.75) of 92% moisture stillage yielded for every fermentation batch distilled.

(c) After being run through the centrifuge, the moisture content of the byproduct is approximately 70%. To go from 92% moisture to 70% moisture, 73.3% of the original wet stillage weight must be removed by the centrifuge. This means that 708.63 gal (966.75 x .733 = 708.63) of the original wet stillage volume are removed.

(d) There are 258.12 gal of 70% moisture byproduct left after the original 966.75 gal of 92% moisture stillage have been run through the centrifuge (966.75 - 708.63 = 258.12).

(e) One gallon of 70% moisture byproduct weighs approximately 8 lb, so there are 2,064.96 lb (258.12 gal x 8 lb/gal = 2,064.96) of 70% moisture byproduct yielded per fermentation batch.

(f) 2,064.96 lb are equal to 1.03 ton.

(g) According to the above estimate, 1.03 ton of 70% moisture by-product are yielded for each fermentation batch that is distilled.

(h) On an annual basis, 50.5 ton of byproduct per year are yielded in Tables 1 and 2, and 101 ton per year are yielded in Tables 3 and 4.

(2) Value

(a) As previously stated, for each bushel of corn utilized in the production process, there will be approximately 25 gal of 92% moisture stillage yielded. This 25 gal of 92% moisture stillage contains about 17 lb of solids, which are referred to as Distillers Dried Grains (DDG) when they are dried down to 10% moisture content in the commercial feed industry. DDG is about 27% protein, as compared to 44% protein in soybean meal (SBM).

(Annex E, continued)

(b) Wholesale prices of DDG usually run about 65% to 75% of the price of SBM at Chicago. If the values of the two are compared on a nutrient content basis, use of least-cost ration analysis for cattle indicates DDG should be worth from 40% to 70% of the price of SBM. For the purposes of this paper, it is assumed that DDG is worth 60% of the retail price of SBM. If SBM is retailing for $200 per ton, then DDG would be worth about $120/ton.*

(c) However, we are not dealing with DDG at 10% moisture. We are dealing with an undried feed byproduct at about 70% moisture after it has been run through a centrifuge. If we assume that the centrifuge process retains the protein value of the byproduct, the 1.03 tons or 258.12 gal of 70% moisture byproduct should have the equivalent in feed value of 657.39 lb of DDG (38.67 bu of corn times 17 lb solids/bu of corn = 657.39 lb).

(d) 657.39 lb are equal to .3287 ton.

(e) .3287 ton times $120/ton (value of DDG) = $39.44.

(f) $39.44 per 1.03 ton = $38.29/ton for the 70% moisture byproduct.

(g) Since the 70% moisture byproduct will present some difficulties in handling and storage, a 10% discount against its value is assumed in this paper.

(h) The final estimated value for the 70% moisture byproduct is $34.46 (38.29 x .90 = $34.46) or, rounded off, $34/ton

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*For a more detailed description of the byproduct value calculations, see EMC 837, "Should I get involved in fuel alcohol production? Economic considerations," by Thomas Dobbs, SDSU Cooperative Extension Service, June 1980.

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