FEASIBILITY STUDY

FOR
AN
INTEGRATED ENERGY
SYSTEM

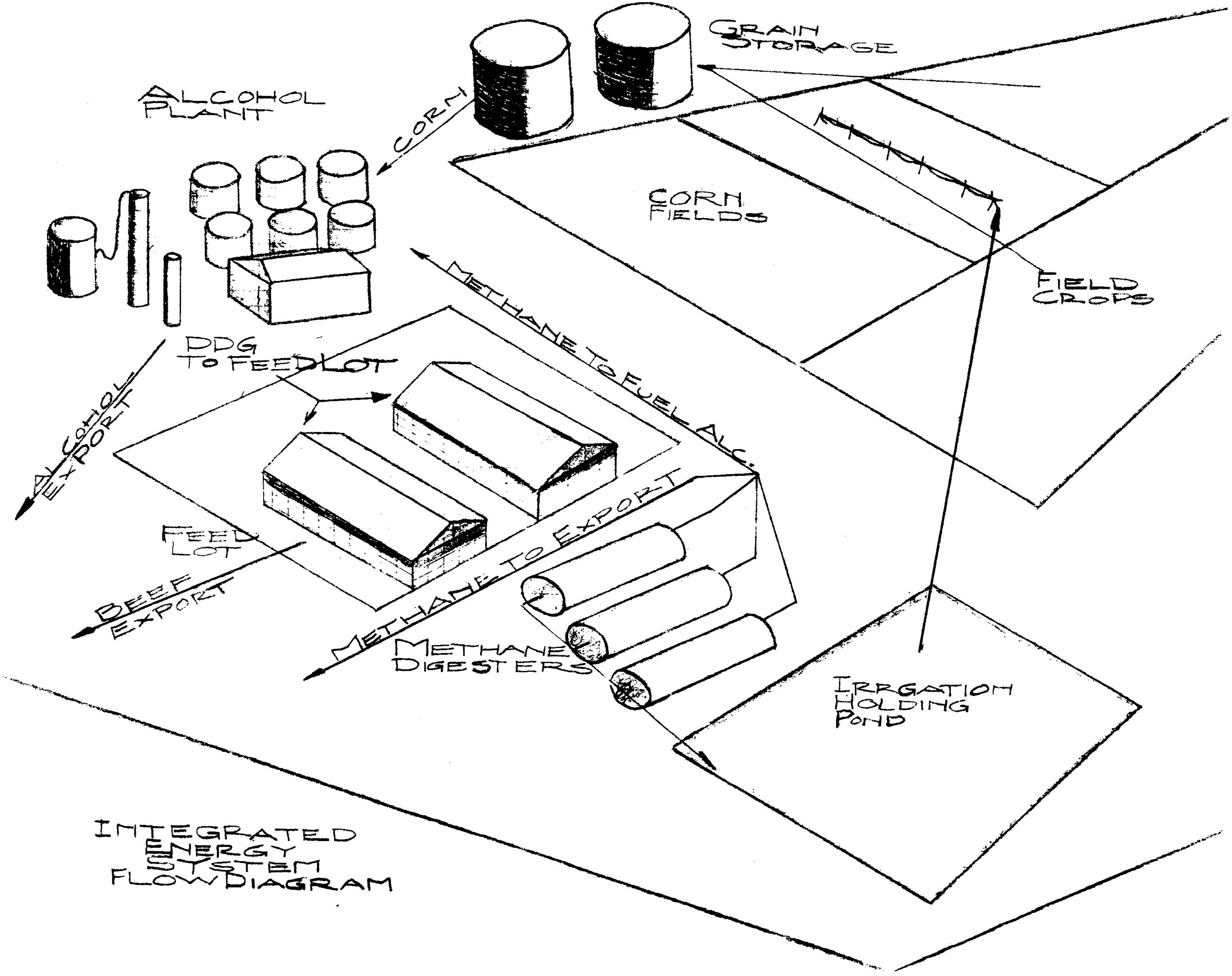
BIO-FUEL

Written by:
Judith M. Harrington
David M. Ellis

TABLE OF CONTENTS

There are no passengers on
Spaceship Earth. Everybody's crew.

--Marshall McLuhan


GRAIN STORAGE
ALCOHOL PLANT
CORN
CORN FIELDS
FIELD CROPS
METHANE TO FUEL ALC.
DDG TO FEEDLOT
ALCOHOL EXPORT
FEED LOT
BEEF EXPORT
METHANE TO EXPORT
METHANE DIGESTERS
IRRGATION HOLDING POND
INTEGRATED ENERGY SYSTEM FLOW DIAGRAM

This feasibility study has been written to give you an idea of how alcohol fuels can affect your present, and how you can become involved in a nationwide effort to take control of your energy future. In reading it, you will come to understand how the new technology of biofuel can help solve our country's fuel problems. This technology is renewable, clean, small community-oriented, and profitable.

The research for this study has taken over two and a half years. It has encompassed not only farm/homestead scale useage of fuel production and energy conservation, but also research into the localized production of biofuel from resources which are available in a particular area. This could mean wind generators supplying electricity to a coastal town, methane gas for cooking and heating from Texas cattle feedlots, complete solar energy homes in Arizona's desert, or Iowa's small towns run on electricity produced by alcohol stills fed by local corn. Integrating several energy sources produces greater efficiency, making more fuel for less work and money, and even the left-overs can be recycled!

We hope that this study will make you aware that we stand on the edge of a new energy future. We believe that alcohol fuel is the biofuel that should be exploited first, in order to start the ball rolling, since alcohol technology has already made great strides into the nation's economy. Hopefully, you will agree with us enough to want to play a role yourselves in this new economy.

Man alone (of all the creatures
of earth) is the architect of his destiny.
--William James

IS THERE AN ENERGY SHORTAGE?

The standard formula for determining fuel supply is to take the known reserves and divide them by annual consumption to determine how long our fuel will last. This method is subject to vast error since it does not project probable reserves plus percentage of increase in usage. Even if we include the probable reserves (backed by strong geological evidence), our projection can still fall short because of increased use.

Mr. M. King Hubbert, author of U. S. Energy Resources, A Review as of 1972, written for the Senate Committee on Interior and Insular Affairs, seems to have developed a more realistic analysis of this problem. He finds that for any stock-limited resource the production cycle can be manipulated by several phases: first, increasingly rapid growth in the rate of exploitation as demand rises, thus making production more efficient, which reduces the per unit cost of the material; then a leveling off of production as the resource becomes scarce, which increases price; and last, a continuous decline in exploitation as cost becomes prohibitive due to increasing scarcity. This stage stimulates the way for substitutes to be brought in.

Figure 1 is a generalized illustration of Hubbert's production cycle. The year in which the fuel consumption reaches its peak is Yp and Y_{90} represents the point at which 90% (that which is possible to extract) of the ultimately recoverable resources have been extracted.[1] Ultimately recoverable resources describes the total amount of a material which could be located within the earth based on geological data about the earth.[2]

NOTE: Even the oil companies themselves recognize the need for new sources of fuel. In Exxon Corporation's 1980 Annual Report, the Board of Directors state that, "By the end of the century, we expect total energy demand in the United States to be somewhat higher than it is today, but the share of total energy supplied by oil and natural gas will decline from around 75% to about one-half. That assumes that stepped up drilling efforts will result in new discoveries, particularly in frontier areas, to offset declining production from mature fields. Some of the difference will be made up by increased use of directly burned coal and nuclear fission . . . . The gap between demand and the domestic supply of these fuels creates the opportunity for development of a synthetic fuels industry." Exxon Corporation goes on to explain their belief that coal and oil shale resources should be exploited. While these may be classified as "synthetic fuels," they are certainly not renewable, nor are they clean.

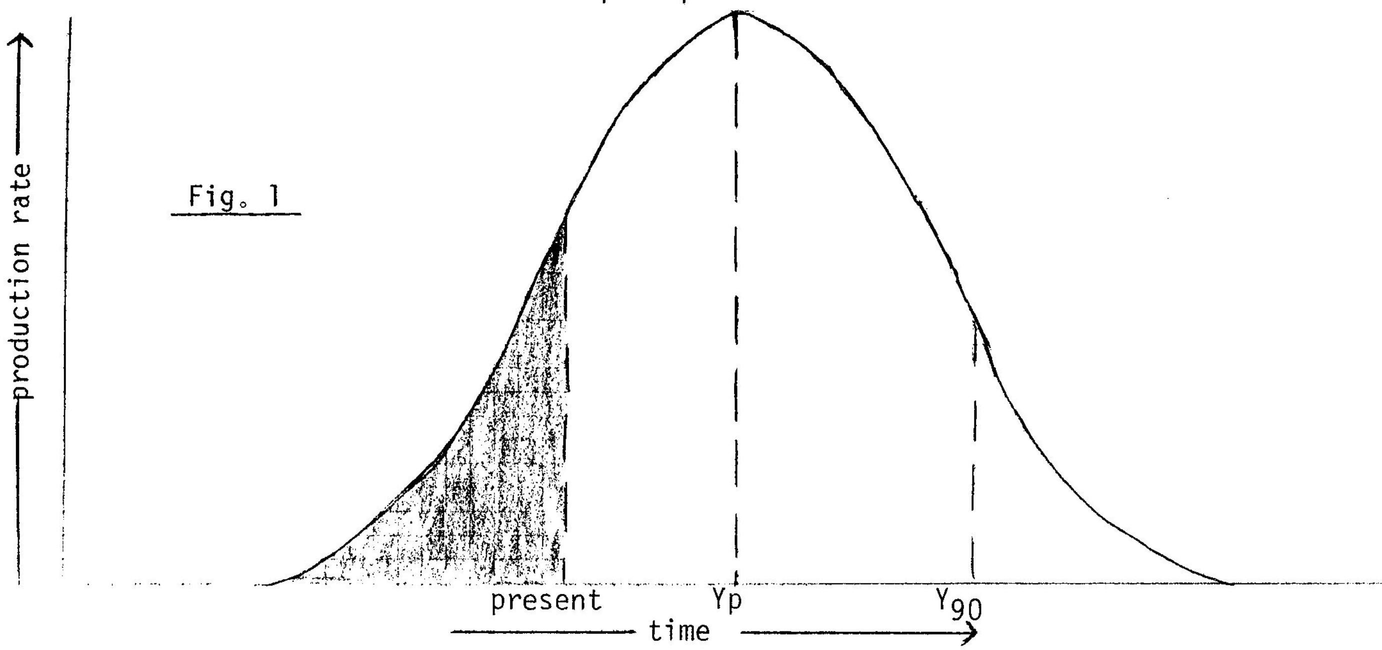


Fig. 1

	At 1972/73 rate of consumption (years)	At 2.5%/yr increase in consumption (years)	At 5%/yr increase in consumption (years)	Date of Yp	Date of Y_{90}
UNITED STATES					
Petroleum liquids (lowest)	17	14	12	1970	2000
Petroleum liquids (highest)	97	49	35	2010	2050
Natural gas (lowest)	28	21	18	1980	2015
Coal	2800	171	99	2220	2450
WORLD					
Petroleum liquids (highest)	99	50	36	2000	2030
Coal	2900	172	100	2150	2400

Fig. 2

Consequences of Worst-Cast Hypothetical LWR Accident as Estimated by the Rasmussen Report

Effect	Rate or number	Duration	Total number, Rasmussen best estimate	Uncertainty range, multiplicative	Total number, Rasmussen low estimate	Total number, Rasmussen high estimate
Prompt deaths	3,300	-	3,300	1/4-4	825	13,200
Cancer deaths	1,500/yr	30-40 yr	45,000-60,000	1/6-3	7,500	180,000
Prompt illnesses	49,500	-	49,500	1/4-4	12,375	198,000
Thyroid illnesses	8,000/yr	30-40 yr	240,000-320,000	1/3-3	80,000	960,000
Genetic effects	190/yr	many generations*	28,500	1/6-6	4,750	171,000
Property damage	$14 billion	-	$14 billion	1/5-2	$2.8 billion	$28 billion

*Equivalent to 150 years at constant rate.
Source: U.S. Nuclear Regulatory Commission, Reactor Safety Study.

Fig. 3

He will manage the care best who forsees what is to happen
from the present condition of the patient.
-Hippocrates, ca. 460-377 B.C.

When men lack a sense of awe, there will be disaster.
-Lao Tsu, ca. 600 B.C.

(p. 4, "Consequences of Worst-Case"

Figure 2 shows the lifetimes of conventional fossil-fuel resources, and the projected years of Yp (consumption at its peak) and Y_{90} (90% having been extracted) based on Hubbert's method.

Based on Hubbert's data, we can see that within our lifetime, and most definitely within our children's lifetime, there will be no more petroleum and natural (methane) gas. We need to take action now.

We do not advocate the use of nuclear technology in its present form, and wish to point out some of the known hazards. Figure 3 speaks for itself. Under nuclear attack of a nuclear power plant, these findings need to be doubled. If you are unaware of radioactive half life, here's an example: take 1,000 oranges with a half life of seven days (one week). After one week, 500 oranges would go bad. After another week, 250 would go bad, after seven more days, 125 would go bad, etc. It's the same with nuclear waste.

We will never see the elimination of nuclear waste on this planet if we stop all production today! Plutonium's half life is 24,400 years. Neptunium -237 has a half life of 2,100,000 years.[3]

How much waste is there? If it were concentrated into its most compactable form, for each person served there would be a total of 2,000 cm^3 of low and high level waste, or about 3,000 to 3,600 aspirin tablets per person per year served.[4] An aspirin's average weight is 5 grams, which is equal to 77.15 grains each. One grain of plutonium -237 waste will give you terminal cancer![5]

THE ECOLOGICAL CYCLE OF A METHANE-ALCOHOL FUEL SYSTEM

CORN

Irrigated land is producing 150 bushels per acre.[6] One bushel = 2.5[7] gallons ETOH, which equals 375 gallons ETOH/acre. The co-product of ETOH production using corn as the starch source is Distiller's Dried Grain (DDG). One bushel of corn produces 17.5 pounds of DDG.[8]

DDG

150 bushels of corn will produce 2,625 pounds of DDG. One medium cow (600+ pounds) can consume 24 pounds of mixed feed per day.[9] Wet DDG contains 9-13% protein, while dried DDG contains 28-30% protein.[10] DDG can be mixed with spent manure from a methane digester, which balances out the protein/fiber ratio. Assuming that a cow consumes 17.5 pounds of DDG per day, the remaining 6.5 pounds of feed can contain spent manure. BioGas of Colorado[11] found that standard feed can be cut by as much as 16% with dried spent manure without reducing weight gains by a substantial amount. Medium sized cows gain approximately 2.5 to 2.75 pounds per day when fed in a feedlot.[12] Weight gain increase during the fall and winter months, and decreases during the spring and summer months. 150 head of cattle can gain a total of 412.5 pounds per day under feedlot conditions. The co-product of feeding cows DDG is manure.

MANURE

One cow (600+ pounds) produces enough manure to produce 30 cubic feet[13] of methane gas. One cubic foot of methane gas is equal to 650 BTU. 150 cows will produce approximately 4,500 cubic feet of methane per day. Methane gas is very difficult to store because it must be refrigerated to under -200^{o}F. If the methane is converted to electricity, 150 cows will produce 856.44 kilowatt hours per day. This figure does not account for a 10% to 20% loss of energy in the conversation process. The co-products of feeding manure through a methane digester are organic fertilizer and feed matter for cattle.

FEED PRODUCT

By running the manure through a separator, the solids can be removed from the liquid. The solids can then be used as a substitute for hay and other fiber sources. In a performance summary conducted by BioGas over a period of 140 days, it was concluded that cows fed residue manure gained .18 pounds less per day than cows fed the standard feedlot feed, which is a milo base. The cows consumed an average of 1.53 fewer pounds of treated feed compared to the standard milo feed per day.[14] This reduction in feed intake showed the feed/gain ratio of treated feed to be slightly higher than the standard feed's feed/gain ratio.

ORGANIC FERTILIZER

After the manure leaves the digester, it is highly liquified. This liquid contains nitrogen, potassium, phosphate and other minerals. It can be sold as a high-quality liquid fertilizer, used as fertilizer for corn production, or the production of high-quality organic vegetables and fruits. The typical fertilizer requirements for producing one acre of corn are: 90 pounds nitrogen, 80 pounds phosphorus, 150 pounds potassium. One cow produces approximately the following amounts of fertilizer in a year's time: 62 pounds nitrogen, 40 pounds phosphorus, 45 pounds potassium. Therefore, two cows will provide 65% of the nitrogen, 100% of the phosphorus, and 64% of the potassium needed to grow that acre of corn.[15] Assuming the acre is irrigated, it is expected to produce 150 bushels of corn.[16]

The soil from a field at the experimental station in Tifton, Georgia has had liquid manure spread on it for the last seven years. The following was observed: the soil there is generally a sand base; however, the soil in this field was black and had a high humus content. It was soil, not sand.

The information contained in this ecological cycle outlook shows that an alcohol/methane fuel system is a highly efficient ecosystem. The corn passes through four different stages, each of which creates a marketable co-product(s). Considering that most corn farmers only cash in on their crop once makes this system look promising from a financial viewpoint.

FINANCIAL ANALYSIS OF ALCOHOL/BIOGAS FUEL PRODUCTION

Assuming the alcohol still produces 5,000 gallons of 200 proof alcohol per day, there will be 17.5 tons (dry weight) of DDG produced as a by-product.

Based on information from Corral Industries of Arizona, 17.5 tons of DDG at approximately 30% moisture will feed 2,000 head of cattle per day.[17] They report that cattle feed can be cut by 60% with DDG in a moist form.[18] A cow of 700 pounds will consume 28 to 30 pounds of feed per day. 28 pounds less 40% = 16.8 pounds. Since this 16.8 pounds is the minimum intake for the minimum weight cow, it can be assumed that 17.5 pounds of DDG at 30% moisture can be consumed by one cow at 700 pounds plus.

BioGas of Colorado has found that the left-over solids from a biogas digester can be fed to cattle without a noticeable loss of weight.[19] The maximum amount of digester residue which was successful was 16%.[20] Therefore, a biogas/alcohol fuel plant can supply 76% of the feed required for the cattle. Although it seems quite possible to feed cattle DDG, digester residue and nutritional supplements, no studies are available to show weight gain or health of the animals. The following figures are based on the DDG and residue being the only feed.

2,000 head of cattle will gain approximately 5,000 pounds per day (one cow gains 2.5 pounds/day x 2,000 head).

The manure from 2,000 head of cattle will produce 60,000 cubic feet of biogas per day. (One cow will produce 40 cubic feet of gas per day, from which 10 is used for heat regulation. This leaves a net of 30 cubic feet per day per cow.)

Grain-fed beef will bring approximately $.50 per pound on the market. Therefore, 2,000 head of cattle are increasing in value by $2,500 per day.

Biogas (unfiltered gas) has a BTU value of 650 BTU/ft^3.[21] 60,000 ft^3 gas x 650 BTU/ft^3 = 39,000,000 BTU/day. 39,000,000 BTU x 2.928 x 10^{-4} - 10% = 10,277 kilowatt hours per day. Assuming the wholesale price of electricity is $.05/KWH, the biogas has a value of $513 per day.

INCOME FROM BIOGAS AND CATTLE

60,000 cubic feet biogas = $513/day x 365/yr	=	$ 187,245
2,000 head of cattle = $2,500/day x 365/yr	=	912,500
Income from manure fertilizer unknown	=	
Total gross income per year		1,099,745
Less total gross income from sale of DDG		895,125
Net income		$ 204,620

Using gross incomes, a plant can earn $204,602 more by setting up a feedlot operation and utilizing its own DDG. Assuming it requires 30% of the plant's gross income to cover expenses, it would leave a net of $143,234 per year as net profit.

The cost for building an alcohol fuel plant which will produce 5,000 gallons of 200 proof ethanol per day is $975,000 as of March, 1981. Allocating $100,000 per year for the investment payback, the plant will pay for itself in ten years. The design and plans for the plant are completed.

The methane digester system, including 2,000 head of cattle, will cost approximately $1,760,000 to construct. The final design and plans for the system have not been completed; therefore the figure quoted is an estimate only.

PER YEAR FINANCIAL OUTLOOK OF ELLIS ENTERPRISE ALCOHOL PLANT

The following financial outlook is based upon the following:

Corn	:	$150 per ton
Electricity	:	$.08 per gallon
Enzyme and yeast	:	$.10 per gallon
Miscellaneous (transport of corn, DDG, etc.)	:	$.10 per gallon
Sawdust	:	$8.00 per ton

PRODUCTION COST/YEAR			
Corn - 17,920 tons x $150	=	$2,688,000	
Fuel - 6,400 tons x $8	=	51,200	
Electricity - $.08 gal x *1,600,000 gallons	=	128,000	
Enzyme - $.10/gal x 1,600,000 gallons	=	160,000	
Misc - $.50/gal x 1,600,000	=	80,000	
Maintenance $.08/gal x 1,600,000	=	128,000	
Insurance	=	5,000	
Loan Payment (Dividends)	=	100,035	
Salaries	=	120,000	$3,455,235
INCOME			
Sale from alcohol (1,600,000 gal x $1.75/gal)	=	$2,800,000	
Sale from DDG (5,440 tons at 10% moisture x $130/ton)	=	707,200	$3,507,200
NET CORPORATE GAIN			$ 51,965

*1,600,000 gallons ETOH produced per year

ETHANOL PRODUCTION

The production of fuel-grade alcohol (ethanol) from corn is a fermentation process which involves heat (cooking of corn), thermophylic bacterial amylases, glucoamylase, and yeast cells (Saccharomyces cerevisiae). The heat and thermophylic enzymes break down the starch to polymeric sugars known as dextrins. These dextrins are further degraded to the simple sugar glucose by the action of the enzyme glucoamylase. The yeast ferments the glucose by a catabolic reaction which produces alcohol and carbon dioxide. The alcohol is then collected and concentrated by distillation. Anhydrous alcohol (200 proof) is produced by passing the distilled alcohol (195 proof) through an anhydrous tower which extracts the remaining water molecules.

ETHANOL PRODUCTION PROCEDURE

This procedure is calculated for a 4,000-gallon run of 200 proof (100%) ethanol (C_2H_5OH). Both corn and sorghum have a maximum potential yield of 2.6 gallons of 200 proof ethanol per 56 pound bushel.[22] In order to produce 4,000 gallons of 200 proof ethanol, 1,540 bushels of corn will be required.

$$\frac{4{,}000 \text{ gal ethanol}}{2.6 \text{ gal ethanol/bu}} = 1{,}538.5 \text{ bushels}$$

The corn is ground into a meal which is 3/16", or so it can pass through a 20-mesh screen.[23] It should not be ground into a flour or it will tend to form cakes which will inhibit starch exposure to heat and enzymes. The grinding of the corn exposes the starch so that it can be converted into sugar. The corn meal is added to the cooking vessel and is mixed with water.

The water/corn ratio is 20 gallons of water per bushel of corn.[24] Therefore, 36,800 gallons of water are mixed with the corn meal. This will produce a slurry that is about 40% starch. This starch consists of approximately 20% amylase and 80% amylopectin molecules.[25] These starch molecules will be converted to dextrins by enzymatic hydrolysis reaction. This reaction will consist of adding approximately 42 pounds of thermophilic amylase enzyme and heating the mixture to 200^{o}F (90^{o}C) for 1/2 hour.[26] This conversion can be checked by a visual inspection.

Incomplete conversion will be noticed by white specks or lumps or starch. Complete conversion is indicated by a thin fluid mash. In time, one should be able to detect conversion by the smell of the mash. During this enzymatic hydrolysis action, the mash should be agitated with an agitator turning at approximately 35 revolutions per minute (RPM).[27]

During the process the pH should be neutral (pH 7.0).[23] An acid pH can be raised by adding basic solutions such as sodium hydroxide or lime. If the pH is too high, sulphuric acid or lactic acid can be added to balance it.

Once the starch has been broken down to dextrins, the saccarification process can begin. The temperature of the mash should be lowered to between 140^{0}F (60^{0}C) and 122^{0}F (50^{0}C).[29] This temperature range should be maintained during this stage or enzymatic activity is greatly reduced. Furthermore, the pH must be held below 6.5 and should not drop below 4.0[30] The enzyme used during this process is glucoamylase.[31] The amount of glucoamylase to be used cannot be stated, as the amounts differ greatly from one strain to another. The time requirement for this process will vary also with the glucoamylase used. Most glucoamylases will convert the dextrin to glucose in approximately 30 to 45 minutes, provided the suggested temperature, pH and amount of enzyme are used.

There are enzyme companies which combine the glucoamylase and the thermophylic amylase enzymes into one product. This can reduce cost and pH and temperature changes. A close investigation of the different companies' enzyme production rates is necessary before choosing the brand which this system will employ.

The final stage of conversion to ethanol is fermentation. The fermentation process will involve using the enzyme strain yeast Saccharomyces.[32]. The Saccharomyces are classified as facultative organisms. This means the organism can live in environments containing oxygen and in those which do not. Upon introducing the yeast, the mash should be aerated to induce rapid yeast growth. The aerating time should not exceed ten minutes. Once the oxygen is consumed, the fermentation starts and carbon dioxide and ethanol are produced. The temperature range for fermentation is between 80^{0}F and 90^{0}F (35^{0}C).[33] The conversion of glucose to ethanol is a chemical reaction which also produces heat. Therefore the fermentation tank must contain a cooling system. The pH of the fermentation process is most productive between 3.5 and 5.0.[34] The fermentation will take anywhere from 36 to 60 hours to complete.[35] The alcohol content is checked with a saccharometer. In the beginning of fermentation, the specific gravity of the mash should be checked with the saccharometer. It should read 1.080 (8 to 12% alcohol potential). Once fermentation is complete, the meter should drop to 1.007 or less.[36] This can be double-checked by using standard glucose test strips available at drug stores. The test must read negative.

ENERGY REQUIREMENTS

ENERGY REQUIREMENTS FOR COOKING OF MASH

Water requirements for cooking = 40,000 gallons per day.

$$\frac{40{,}000 \text{ gallons}}{2} = 20{,}000 \text{ gal}$$

Because of the amount of alcohol being produced daily, 5000 gallons, it would be unwieldy to work with one large batch, as the size of vessels needed to contain such large amounts of mash, etc. would be prohibitive in this operation. Therefore, two smaller runs each day will be produced, yielding 2500 gallons each.

Tank size:

20,000 gallons of water x 1.337×10^{-1}	= 2,674 cu ft
1,000 bushels of corn x 1.2445	= 1,244.5 cu ft
Total cubic feet of cooker	= 3,918.5 cu ft

Given the diameter of the cooker and fermenters as 12 feet, the height is $\frac{\text{volume}}{\pi r^2}$ = 34.647 feet. The actual size of the cooker and fermenters will be 12 feet diameter by 35 feet high, which equals 3,958 cubic feet.

Area = $(2\pi r)(h + r)$ = 1,545 sq ft

Area heat loss = (15 BTU/ft^2/hr) (9274 sq ft) = 23,175 BTU/hr

Energy requirements:

20,000 gallons water = 166,740 pounds

1,000 bushels corn = 56,000 pounds

Total pounds of mash = 222,740

Assuming the supply of water is coming in at 40°F, and a cooking temperature of 200°F is required, the ΔT is 160°F.

222,740 pounds of mash
x ΔT 160°F
35,638,400 BTU to heat mash

Assuming four hours to heat 222,740 pounds of mash to 200°F:

$$\frac{35{,}638{,}400 \text{ BTU}}{4 \text{ hours}} = 8{,}909{,}600 \text{ BTU/hr}$$

8,909,600 BTU/hr to heat mash
+ 23,175 BTU/hr of area heat loss
8,932,775 total BTU/hr to heat mash

$$\frac{8{,}932{,}775 \text{ BTU/hr}}{33{,}750 \text{ BTU/hp/hr}} = 265 \text{ hp}$$

265 hp x 34.5 lbs of steam/hr = 9,142.5 lbs of steam/hr.

The above energy requirements can be greatly reduces by employing the heat recovery unit as described below.

HEAT RECOVERY UNIT

In this plant, there is one area where a sizeable amount of energy can be saved. This can be accomplished by taking the hot waste water coming from the vapor condensers and putting it into the cooking vessel. In addition to this, the heat from the spent mash can be captured to preheat the cooking water.

If no heat recovery system is used, it would take 35,731,100 BTU to raise the mash from 40°F to 200°F over a four-hour period. The flow coming off the two condensers is 4,896 gallons per hour at 150°F. Therefore, it will take four hours and 10 minutes to fill the cooking vessel.

The spent mash coming off the distillation unit will have a temperature of approximately 195^{o}F. By taking this spent mash and passing it through a heat recovery unit (Tranter Superchanger Model #UX216-HP-50), 1,983,366 BTU/hr can be recovered. This assumes that the incoming cooling water is at 60^{o}F. This water will leave the heat recovery unit at 118^{o}F. The flow rate of the water will be 4,116 gallons/minute. This pre-heated water will be piped into the waterline coming off the condensers. By adding the flow rate of these two lines together, the total flow of approximately 125^{o}F pre-heated water will equal 9,012 gallons per hour (GPH). At this rate of flow, it will take two hours and 12 minutes to fill the cooker. The pre-heated water will pass through another Tranter Superchanger, which will raise the water temperature to 200^{o}F. The BTU requirement for this Superchanger is 3,756,650 BTU/hour. That is a savings of 32,593,392 BTU/day, or 2.2 cords of pine per 24-hour day, when compared to using cold spring water.

ENERGY REQUIRED FOR COOKING OF MASH UTILIZING HEAT RECOVERY UNIT

71,462,200 BTU required using no heat recovery system per 24 hours

(8,932,775 BTU/hr) (4 hours/batch) (2 batches/day) = 71,462,200

Implementing the recovery system:

9,012 GPH at 125^{o}F = 75,133 pounds of water/hr at 125^{o}F

75,133 pounds H_2O/hr
x ΔT 75^{o}F (200^{o}F maximum cooking temperature - 125^{o}F temperature of pre-heated H_2O = ΔT 75^{o}F)
5,634,975 BTU/hr

(5,634,975 BTU/hr) (2.16 hours) = 12,171,546 total BTU to heat the water for one batch

56,000 pounds corn X .92 (S.H.) X 140^{o}F ΔT = 7,212,800 BTU to heat the ground corn to 200^{o}F (for each batch)

$$\frac{7{,}212{,}800 \text{ BTU}}{2 \text{ hours}} = 3{,}606{,}400 \text{ BTU/hr for two hours}$$

Total energy to heat mash = 7,212,800 BTU for corn/batch
12,171,546 BTU for water/batch
50,058 BTU area heat loss/batch
19,434,404 Total BTU required to heat one batch of mash

(19,434,404 BTU/batch) (2 batches/day) = 38,868,808 BTU/day

38,868,808 BTU/day using heat recovery system

71,462,200 BTU/day without heat recovery system
-38,868,808 BTU/day using heat recovery system
32,593,392 BTU/day saved

$$\frac{71{,}462{,}200}{15{,}000{,}000 \text{ BTU/cord of pine}} = 4.8 \text{ cords/day}$$

$$\frac{38{,}868{,}808}{15{,}000{,}000} = 2.6 \text{ cords/day total fuel consumed}$$

4.8 - 2.6 = 2.2 cords of pine/day saved

Steam Requirements:

$$\frac{5{,}635{,}000 \text{ BTU/hr to Tranter Superchanger for } H_2O}{33{,}750 \text{ BTU/hp}} = 169 \text{ hp/hr}$$

(169 hp/hr) (34.5 pounds of steam/hp) = 5,830 pounds of steam/hr

$$\frac{3{,}606{,}400 \text{ BTU to cooker steam/water jacket}}{33{,}750 \text{ hr/hp}} = 107 \text{ hp/hr}$$

(107 hp/hr) (34.5 pounds of steam/hp) = 3,691.5 pounds of steam/hr

DISTILLATION UNIT

Energy required to operate reboilers:

Column 1 = 45,840 BTU/minute = 2,750,400 BTU/hour

Column 2 = 39,840 BTU/minute = 2,390,400 BTU/hour

Total = 85,680 BTU/minute = 5,140,800 BTU/hour

Column 1 = 2,750,400 BTU/hr

$$\frac{2,750,400 \text{ BTU/hr}}{33,750 \text{ BTU/hp}} = 81.5 \text{ boiler hp}$$

(81.5 hp) (34.5 lbs of steam/hp) = 2,811.75 lbs of steam/hr

Column 2 = 2,390,400 BTU/hr

$$\frac{2,390,400 \text{ BTU/hr}}{33,750 \text{ BTU/hp}} = 71 \text{ hp/hr}$$

(71 hp/hr) (34.5 lbs of steam hp) = 2,449.5 lbs of steam/hr.

Energy required to heat feed to Column 1:

Assuming the mash leaves the fermenter at $80^{o}F$, that gives a ΔT of $132^{o}F$.

(83.3) bushels corn/hr) (56 lbs/bu) = 4,664.8 lbs corn/hr.

(83.3 bu corn/hr) (20 gal H_2O/bu) (8.337 lbs/gal) = 13,889.5/hr of H_2O.

Total lbs of mash per hour = 18,554.3

18,554.3 lbs of mash/hr ΔT $132^{o}F$ = 2,500,000 BTU/hr

$$\frac{2,449,168 \text{ BTU/hr}}{33,750 \text{ BTU/hp}} = 72 \text{ hp/hr}$$

(72 hp/hr) (34.5 lbs of steam/hp) = 2,504 lbs of steam/hp.

Energy required to heat feed to Column 2:

When the vapors are condensed, the liquid will be just under the boiling point of the alcohol and water. Assuming the condenser is operated at the proper flow, the energy required to evaporate the alcohol is minimal.

The vapor leaving Column 1 contains 76% by volume ethanol, and has a boiling point of 79.7°C (175.5°F). Assuming that the condensed vapor drops 5°F, then 11, 255 BTU/hr will be more than required to revaporize the ethanol.

$$\frac{11{,}255 \text{ BTU/hr}}{33{,}750 \text{ BTU/hp}} = .33 \text{ hp}$$

(.33 hp) (34.5 lbs of steam/hp) = 11.4 lbs of steam/hr.

STEAM LINES

Steam Lines	Pipe Size (nomial)	Pounds of Steam/hr
A to cooker (Superchanger)	3½"	5,830
B to cooker (jacket steam heater)	3"	3,691.5
C to reboiler Col. 1	3"	2,812
D to reboiler Col. 2	3"	2,449.5
E feed heater Col. 1	3"	2,504
F feed heater Col. 2	1"	11.5
G to feed heater for azeotropic distillation column	1"	10 (maximum)
H to reboiler for azeotropic column	3"	1,697*
Trunk line for A-B	4"	
Trunk line for C-G	4"	
Total		19,305

$$\frac{19{,}305 \text{ lbs steam/hr}}{34.5 \text{ lbs steam/hp}} = 560 \text{ hp/hr}$$

*Provided by Metex Equipment Corporation

FUEL REQUIREMENTS

225,000,000 BTU/day consumed

Assuming 7500 BTU/pound of sawdust

225,000,000 BTU/day x 30% efficiency factor = 292,500,000 BTU input into boiler/day

$$\frac{292{,}500{,}000 \text{ BTU/day}}{7{,}500 \text{ BTU/lb sawdust}} = 39{,}000 \text{ pounds of sawdust/day}$$

$$\frac{39{,}000 \text{ lbs sawdust}}{2000 \text{ lbs/ton}} = 20 \text{ tons of sawdust per day}$$

ENERGY EFFICIENCY

Assuming 100% ethanol has a BTU content of 76,152 BTU per gallon:

5,000	gallons/day of 95% ETOH
x76,152	BTU/gallon
380,760,000	BTU produced per day

38,868,800	BTU/day for cooking
126,000,000	BTU/day for reboilers
60,000,000	BTU/day for mash pre-heater
225,000,000	total BTU consumed

380,760,000	BTU/day produced
225,000,000	BTU/day consumed
155,760,000	BTU/day gained

This system produces a net energy gain, as can be seen from the above figures. No other energy producing system can claim that!

METHANE GAS PRODUCTION

The methane gas which will be produced is properly called biogas. This name is derived from the fact that the gas is made from animal (and other) waste in a biochemical environment known as an anaerobiosis.[37] This means the methane-producing bacteria live in an oxygen-free environment. Biogas does contain methane gas (CH_4). However, it also contains carbon dioxide (CO_2), water vapor (H_2O), and sometimes nitrogen gas (N_2), hydrogen sulfide (H_2S), and hydrogen gas (H_2). Due to these added elements, the BTU value of biogas is lower than the BTU value of methane gas. On the average, biogas contains 650 BTU/ft^3, while methane gas contains 1000 BTU/ft^3.[38] These are only averages, and in fact a well-operating digester may produce higher BTU gas than is found in the natural gas lines in some cities.

The BTU value of biogas can be raised by passing the gas through a CO_2 scrubber.[39] Since CH_4 and CO_2 comprise 95 to 99% of most biogas, removal of the CO_2 yields a relatively pure methane gas.[40] Since CO_2 is inert, removing it will raise the BTU value of the biogas to that of the gas found in many natural (methane) gas lines. Homemade CO_2 scrubbers can be made by passing the gas through an alkaline solution -- calcium hydroxide (CaOH), or sodium hydroxide (NaOH), and water. A commercial CO_2 scrubber is more efficient, however, less trouble, and it eliminates the possibility of skin burns which can otherwise result from CaOH or NaOH solutions contacting the skin.[41]

Since the plans call for the biogas to power an electrical turbine, the H_2S will need to be removed. The reason for this is that the H_2S will corrode the turbine.[42] H_2S scrubbers are available which require annual maintenance.

Biogas production is governed by three factors. These are the temperature, pH and carbon/nitrogen ratio of the substrate.[43] The substrate can be nearly any organic matter which contains carbon and nitrogen.[44] Presently there are three known families of bacteria which will produce biogas. They are psychophiles, mesophiles, and thermophiles.[45] Temperature is the number one factor controlling the life of these bacteria. The psychophilic bacteria live in a temperature range of 0 to 20^oC (32^o to 68^oF), and do not grow at higher temperatures. They are also extremely sensitive to pH and C/N ratio changes. For these reasons, this bacteria will not be used in the proposed plant. The mesophilic bacteria are a rather hardy group which grow between the temperatures of 21^o and 45^oC (70^o to 113^oF).[46] The mesophiles are most productive between 32^o and 38^oC (90^o to 100^oF).[47] Since this temperature is easy to maintain and does not require much external heat energy, this bacteria is the indicated one for use in a commercial plant. The following information on pH and C/N ratio applies to both the mesophilic and thermophilic bacteria.

The bacteria prefer a pH range between 6.8 and 8.5 (neutral). Yet they can withstand a pH as low as 5.5.[48] Therefore, it is important to regulate the pH. If the pH is too acid (low), lime water ($CaOH_2$) or lime ($CaCO_3$) can be added to the substrate. Sodium bicarbonate ($NaHCO_3$), among a few other positive ion elements, will also correct an acid problem. All alkaline substances should be added to the substrate in small amounts (0.2 to 0.3 ounces of alkaline source for every cubic foot of substrate).[49] In order to keep a good check on the pH in a commercial operation, an electronic pH tester should be used.

Alkaline problems are uncommon in biogas generation. This problem can be corrected by recirculating CO_2 containing gases, or by raising the carbon/nitrogen ratio.

The third factor in biogas production is the carbon/nitrogen ratio (C/N ratio). Most bacteria (aerobic and anaerobic) use approximately 30 carbon atoms for respiration and growth for every nitrogen atom used.[50] Therefore, optimum gas production can be achieved by using materials with a C/N ratio of 30 to 1. The C/N ratio of beef cattle manure is 28 to 1,[51] which is close enough for high-quality biogas production. The C/N ratio is not an extremely critical factor, and tends to be self-regulating. If there is too much carbon to nitrogen, more CO_2 will be produced, until enough carbon atoms are used to correct the imbalance. A low carbon/nitrogen ratio can be corrected by adding a material with a high C/N ratio. Ground leaves are an excellent source. Biogas plants which utilize many different materials will need to know the C/N ratio, H_2O content, and C + N#* of each. This will provide enough information so that the proper amounts of each material can be calculated in order to maintain the correct C/N ratio.

---

*C + N# is the approximate reciprocal of the percentage of carbon + nitrogen in each substrate times 100: $\frac{100}{\% C + \% N}$

The thermophilic bacteria live in a temperature range of 40^{o} to $60^{o}C$ (104^{o} to $140^{o}F$). The optimum range is 50^{o} to $55^{o}C$. The amount of energy required to maintain this temperature tends to make the use of thermophilic bacteria impractical from an economic viewpoint.

Another drawback to using these bacteria is they tend to produce more H_2S than mesophilic bacteria. However, thermophilic bacteria do have a respectable advantage. Thermophilic biogas generation is said to be at least twice the rate of mesophilic biogas generation.[52] This means that digestion time can be reduced, and the digester vessel can be smaller. The first thermophilic digester has just been built in Israel.[53] Provided the system proves to be highly reliable and efficient, this plant may switch to the thermophilic bacteria.

INTEGRATING THE SYSTEM

An alcohol fuel plant can form the center component of a number of profitable enterprises. Let's use the following as an example.

The town of Yatesville, Georgia has been denied a request for a natural gas line by Atlanta Gas Light Company. Because of Yatesville's small size and isolation from main gas lines, Atlanta Gas Light Company would not make enough profit to justify their installation costs. Ample natural gas, however, can be produced to meet the town's needs by having an alcohol fuel plant operating in conjunction with a feedlot. The DDG produced by the alcohol fermentation is used in the feedlot, while methane gas is produced from the cows' manure. The whole operation can be located within a reasonable distance from Yatesville, and the town's residents profit by having a more convenient and less expensive source of fuel, as well as a boost in local business and job opportunities.

A breakdown of costs follows:

METHANE GAS PRODUCTION OUTLOOK FOR YATESVILLE, GEORGIA

Number of households in Yatesville	=	176
Maximum average home use of methane gas in ft^3	=	x9,000
Yatesville's maximum monthly average use of methane in cubic feet	=	1,584,000
months in year		x 12
Yatesville's yearly average use of methane in ft^3	=	19,008,000

Yatesville's daily maximum use of methane:

$$\frac{19,008,000}{365} = 52,076.7 \text{ ft}^3$$

Number of beef cattle needed to meet Yatesville's gas needs: $\frac{52,076.7}{30} = 1,735$

1,735 cows will consume 30,362.5 pounds of DDG per day.

Bushels of corn necessary to produce 30,362.5 lb of DDG/day: $\frac{30,362.5}{17.5} = 1,735$

Tons of DDG produced per day: 1,735 bu x 17.5 lb ÷ 2000 = 15 tons

In order to produce enough methane gas for Yatesville, an alcohol still which produces 4,337.5 gallons of alcohol per 365 days would be needed. 4,337.5 gal/day x 365 days = 1,583,187.5 gal/yr. 1,583,187.5 gal/yr ÷ 320 working days per year = 4,947 gal/day. 4,947 gal/day ÷ 24 hours/day = 206 gal/hour.

FINANCIAL OUTLOOK

Net price per gallon is $.21 x 1,583,187.5 gal/yr	=	$332,469
Retail price of methane gas is $3.70/mcl x 19,000	=	70,329*
Approximate gross income from cattle production (1,735 head x 2.5 lb/day x 365 day/yr x $.50/lb)	=	791,594
TOTAL GROSS INCOME		$1,194,392

To take our example still further, two more industries could be established utilizing products from the feedlot -- a meat-packing plant which would also produce blood meal and bone meal, and a hydroponic vegetable operation which would need only limited pesticides** and

*9,000 BTU is what Atlanta Gas Light Company estimates as the maximum average use of methane gas. This requirement need only be met during the winter months (November - February). The extra gas can be converted to electricity in the summer and sold to the local power company. For example: 52,000 cu ft methane = 51,220,000 BTU/day. 51,220,000 BTU x 2.928×10^{-4} = 14,997.2 kilowatt hours per day.

**Integrated Pest Management (IPM) would eventually eliminate the use of all chemical pesticides.

eliminate the use of petroleum-consuming equipment. Instead of growing plants in a soil medium, hydroponics uses a sand base and the plants are fed liquid fertilizers. By using the liquid manure left after gas production*, together with ground rock phosphate and granite dust, a highly fertile growing medium can be produced. Ground phosphate rock and granite dust can provide ample phosphorus and potassium, and a host of trace elements. The blood and bone meal with the manure can meet nitrogen and calcium requirements. A hydroponic operation would not use up all the manure and fertilizer, however. The excess can be sold to local grain producers or marketed as a liquid organic fertilizer.

The economics of these last two industries have yet to be researched, although there are similar ones in operation in various parts of the country. Of course, the operating costs of the hydroponic business would be reduced considerably by having all its needs supplied by the other industries (i.e., heat, fertilizer, water, carbon dioxide).

Another example of an integrated system would focus on producing alcohol, methane gas, beef or dairy products and the feedstock for the alcohol operation. This system would be quite different from that of the Yatesville proposal. The system is outlined below.

MODEL II OF AN
INTEGRATED ENERGY SYSTEM

Requirements:	Cost:
**Land -- 3,500 acres	$1,000,000
Irrigation equipment for 3,000 acres	825,000
Farming equipment	175,000
Alcohol fuel plant	975,000
Methane fuel plant	146,000
Feedlot (slatted floors with manure pit)	768,000
2,000 head of cattle	600,000
	$4,489,000
Plus 10% cost overrun	448,900
Total Investment	$4,937,900

*Digestion takes place at a constant temperature of around 100^{0}F for a period of 15 days, which is enough to kill most parasites likely to be harboring in the manure.

**This assumes a double cropping per year of corn and wheat for the feedstock for the alcohol plant.

THE CENTS OF IT ALL

Item	Price/Unit	Amount/Yr	Sales/Yr
Alcohol*	$1.75/gal	1.7 mil. gal.	$2,975,000
Beef	$ .50/lb	1.65 mil. lbs.	825,000
Methane**	$3.75/mcf	19.8 mil. ft^3	74,250
			$3,874,250

Product Cost

Item	Cost	Amount/Yr
Alcohol	$.44/gal	$748,000
Corn/wheat	$.73/acre	438,000
Methane/beef	$50./day	18,250
General operation	$100./day	36,500
Management & engineering	$350./day	127,750
		$1,368,500

Total annual income	$3,874,250
Less yearly production cost	1,368,500
Corporate gain	$2,505.750

HOW ACCURATE ARE THESE ESTIMATES?

The alcohol production costs have been thoroughly worked out. The grain production costs are based on the present corn production cost in Georgia, minus 66% of the fertilizer cost. The beef and methane gas costs are quite high because accurate statistical data are not available. The general operations and management costs include office wages, one plant engineer and adequate skilled labor to keep the process running 24 hours per day, seven days per week.

Detailed information on the figures above will be available after January 1, 1982. Detailed information on the alcohol production aspect is available from Ellis Enterprises for $3.00 each.

---

*$1.75 is the present sell price for 200 proof ETOH.

**The price of natural gas is expected to triple after the deregulation of natural gas goes into effect. This would raise the income from the methane to $222,750, but would not cause the nitrogen fertilizer cost to triple since the system supplies 20-25% of the nitrogen requirements.

FOLLOW-UP

For those of you who are interested in the following, please let us know:

- ATTENDING A LECTURE on this subject to give you a closer look at the industry, and so that we can meet each other; please state your intentions. We will review the input from your area to see if it warrants a visit. If so, we will give you four weeks' notice of the arrangements.

- TO REMAIN ON OUR MAILING LIST, you don't have to do anything. If you do not want to remain on our mailing list, please let us know, and we will remove your name.

- STARTING A BUSINESS OF YOUR OWN.

- INVESTING in a business of this type (be sure, however, to get a legal prospectus before investing in any such venture).

THIS IS NEITHER AN OFFER NOR A SOLICIATION FOR AN OFFER, WHICH OFFER CAN ONLY BE MADE IN CONJUNCTION WITH THE DELIVERY OF A FORMAL OFFERING MEMORANDUM. OFFERS AND SALES MUST BE BASED SOLELY ON SUCH OFFERING MEMORANDUM.

A PERSONAL STATEMENT

My studies in alternative fuels began back in boarding school in Florida. There I learned the concepts of solar and methane gas production, and began to see how they are interrelated. I decided to attend college to further study this field, and with certain goals in mind, I set out to visit the University of California at Berkeley, Colorado University, and Georgia Institute of Technology. I also looked into a host of other colleges, all to no avail. I did not find one college which had a program in integrated appropriate technology. Many had a course or two on the subject, but none offered a degree.

Finally, I contacted Beacon College in Washington, D.C. This college allows a student to work with a program adviser in his/her hometown or state and design a curriculum in a chosen subject area. Three years have passed since that first contact, and I have tailored a program which is making me an expert in the renewable energy field. My education has required me to study chemistry, biology, physics and higher mathematics and computer science at a local college. I have taken a large personal chance: my education has already cost me over $20,000 in preparing me for an industry which has not yet gotten off the ground.

I am a firm believer that life is what we make it. I have been on my own since I was 13. At age 16 I was given my majority, and have traveled throughout the U.S. and Western Europe. My experiences have led me to one major conclusion -- we as a collective entity control our future. Our children's future depends on what we make of it now! It is not government's choice, but yours and mine.

I see two worlds on this planet. The inhabitants of one have abdicated their personal responsibility to large multinationals and world governments.

The people of this world have lost the meaning of personal responsibility, free enterprise and cooperation with their fellow human beings. Their world is spinning out of control and there will be no more personal or economic rewards for them as long as it continues so.

The other world, the one which I support, is made up of individuals with respect for life and this plant which supports it. We recognize the heritage that our founding fathers left to us, and the principles upon which this country was founded. We realize the importance of working together, and that that includes working with all life forms on the planet. We love our children more than money, and want to protect their future, not just our present. We respect the renewal of life and growth and evolution. If personal gain means the disruption of life's evolution, we can do without it. We can wait until sound alternatives are found for producing that which we want.

We cannot blame the old world for it has given birth to the new one. The old world is with us still, for what parent does not want to see his child succeed him?

Our day has come. Our world is spreading. Our respect and love for the Creator is unshakeable; our respect for our health and bodies has created a world-wide industry and spans untold scientific discoveries into human physiology. We now stand upon the final challenge: to harness the secret of evolution which will provide us clean food and energy at no living thing's expense.

David M Ellis

NOTES

1. Paul R. Ehrlich, Anne H. Ehrlich and John P. Holdren, Ecoscience: Population, Resources, Environment, W. H. Freeman & Co., San Francisco, 1977, p. 401.

2. Ibid.

3. Ibid, p. 451

4. Ibid, p. 450.

5. Ibid, p. 454.

6. 1979 Corn and Grain Sorghum Performance Tests, Athens, Georgia: Agricultural Experiment Stations, University of Georgia, 1979, p. 16.

7. Corn Alcohol Farm Fuel, Iowa Corn Promotion Board and Iowa Development Commission, p. 4.

8. Ibid.

9. Donnie Tyler, County Extension Agent for Upson County for the Dooperative Extension Service of the Univeristy of Georgia.

10. Corn Alcohol Farm Fuel, p. 9.

11. John L. Burford, Jr., Fred T. Varani, Don B. Shelly and Bill Pace, Energy Potential Through Bio-Conversion of Agricultural Wastes: Phase III, prepared and submitted by Bio-Gas of Colorado, Inc., 1979, pp. 3-6.

12. Tyler, conversation with.

13. Letter from Susan Schellenbach of Bio-Gas of Colorado, Inc., September 17, 1980.

14. Burford, pp. 3-13, table 7.

15. Tyler, conversation with.

16. Ibid.

17. Proposal, Corral Industries Corporation, 1980, p. 3.

18. Ibid.

19. Burford, pp. 3-10.

20. Ibid.

21. Carol Hupping Stoner, ed., Producing Your Own Power, Rodale Press, Inc., 1974, p. 160.

22. Fuel From Farms, Solar Energy Research Institute, 1980, p. D-6.

23. Ibid, p. 32.

24. Ibid.

25. Ibid, p. 32

26. Georgia Institute of Technology course in integrated energy systems, Dr. Hubbert, professor.

27. Mother Earth News Seminar Manual, 1980, p. 126.

28. Fuel From Farms, p. 37.

29. Ibid, p. 34.

30. Ibid, p. 33.

31. Ibid.

32. Ibid, p. 34.

33. Ibid.

34. Ibid.

35. Mother Earth News, p. 11d.

36. Ibid, p. 12b.

37. Stoner, p. 145.

38. Ibid, p. 160.

39. David House, The Compleat Biogas Handbook, At Home Everywhere, 1978, p. 123

40. Ibid.

41. Mother Earth News Seminar on methane gas production, 1980.

42. House, p. 128.

43. Ibid, pp. 39, 45, 51.

44. Ibid, p. 79.

45. Ibid, pp. 45, 46.

46. Ibid, p. 49.

47. Ibid.

48. Ibid, p. 38.

49. Ibid, p. 41.

50. Stoner, p. 154

51. House, p. 52.

52. The Mother Earth News Magazine, Jan/Feb 1981, p. 166.