ETHANOL PRODUCTION FROM MIXED WASTE PAPER

A PRE-FEASIBILITY STUDY

Prepared for the
Nebraska Energy Office
by
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Lincoln, Nebraska

March 1993

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AUTHORIZATION

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WHAT IS IN THIS REPORT? AN EXECUTIVE SUMMARY

1. An analysis of existing conditions and public policy for both the ethanol and mixed waste paper industries.

2. A process and cost analysis of traditional and emerging ethanol production technologies.

3. An analysis of the ethanol industry with regard to business development.

4. Recommendations for what role the Nebraska Energy Office and the State of Nebraska could take in the development and implementation of the emerging cellulose-to-ethanol technology.

It is now technically possible to produce ethanol from any product having a cellulosic base, including waste paper. However, it is not clear if the cellulose-to-ethanol production technology will hold up under the strains of commercial production as no commercial facilities have been constructed; only laboratory and pilot plants have been tested to date.

Some highlights of the findings include:

Ethanol

* U.S. fuel ethanol production had increased to nearly one billion gallons per year by 1992.

* Archer-Daniels-Midland (ADM), the multinational grain merchandising corporation, currently produces over 70% of all U.S. ethanol. The vast majority of their facilities are located on or near the upper Mississippi River in Illinois and Iowa.

* Corn currently is used as the feedstock for about 90% of ethanol production, but only about one-half of all ethanol plants use corn as their feedstock.

* Ethanol production is currently subsidized at both the federal and state levels. Current federal subsidies include a 10 cent per gallon production credit for the first 15 million gallons produced annually and an exemption of 5.4 cents of the current 14.1 cents of federal gasoline excise tax.

* Nebraska has recently changed its subsidies for the ethanol industry. Allowing a two cent per gallon gasoline tax exemption to expire in 1992, all Nebraska subsidies are now geared to increasing production within the State. These policy changes are estimated to decrease ethanol consumption in Nebraska by 30% annually and increase production seven fold, to over 150 million gallons, by the year 1997.

* Nebraska law is unclear whether non-agriculturally derived ethanol feedstocks would qualify for State ethanol tax incentives.

* The 1990 *Clean Air Act Amendments* will likely be the driving force behind increased use of ethanol blended fuels. Ethanol industry experts estimate that U.S. ethanol consumption could rise to 1.8 billion gallons by the year 2000.

<u>Mixed Waste Paper</u>

* New federal guidelines for the management of municipal solid waste (MSW) have established a hierarchy for dealing with trash. These new guidelines are estimated to significantly increase traditional management costs (landfilling), thereby increasing possible financial benefits of using MSW alternatives.

* Nebraska has also recently adopted far reaching laws for the management of its solid waste. These include a management hierarchy similar to federal guidelines and a landfill volume reduction goal of 50% by the year 2002.

* Waste paper accounts for about 40% of all solid waste, easily the largest segment of the waste stream. This represents about 600 pounds per person per year nationally.

* East central Nebraska likely has a much higher percentage of waste paper than national averages. This is mainly due to the concentration of large insurance companies, a large university system, and many telemarketing firms. Estimates conclude that all waste paper in east central Nebraska may amount to more than 1,000 pounds per person per year.

* Recycling is currently removing 15% to 20% of all waste paper generated in east central Nebraska. However, this recycling is only occurring for certain grades of waste paper, mainly high grade office paper, corrugated cardboard and newspaper.

* Waste paper prices are volatile and vary dramatically depending upon grade and contamination. Waste paper prices currently range from $0 to $100 per ton.

Traditional and Emerging Ethanol Production Technologies

* Ethanol is currently produced from corn by two main processes: dry and wet milling. The wet milling technology is currently used in about 75% of all plants. Both ethanol and various by-products are derived during both processes. It is estimated that nearly all new production of corn ethanol plants will use the wet milling technology.

* Ethanol production from cellulose has been researched and tried for nearly 50 years, but no large-scale cellulose-to-ethanol production facility is currently in operation.

* Genetic engineering of microbes may significantly change the economics of cellulose-to-ethanol technology and reduce commercial risk.

* Yield comparisons between the feedstocks show the corn-to-ethanol process yielding about 90 gallons per ton whereas various grades of mixed waste paper have expected yields of 55 to 75 gallons per ton.

* However, comparisons of feedstocks price on a per gallon of ethanol produced show much closer results. Corn-to-ethanol feedstocks comprise about $0.44 of total cost per gallon whereas various grades of waste paper could cost between $0.20 to $0.90 per gallon of ethanol produced.

Ethanol and Business Development

* Only 38 of the 165 (23%) ethanol plants built in the U.S. since 1979 remain in production. Most closed due to technical failures which destroyed commercial viability.

* Ethanol production is a high risk industry. Statistical analysis on rates of return for the industry suggest a strong relationship between rates of return and risk premium.

* The factor producing the single greatest effect on return on investment is the sales price of ethanol, not the cost of capital, which was second. Descending order of other factors tested were operating costs, feedstock costs, and ethanol yields.

* Ethanol development now is dominated by a large agribusiness corporation which made reasonable decisions in locating production facilities along least-cost transportation routes. Unless there is a radical change in the composition of production and marketing costs (such as a bioengineering breakthrough at the operations scale) it is likely that this existing configuration will remain in place.

SUMMARY OF FINDINGS AND RECOMMENDATIONS

(1) Economic and engineering assumptions on efficiency of scale which hold that only large-size (10 million gallon per year or larger) plants can be commercially efficient, work against Nebraska. Research shows that only in Omaha would sufficient quantities of waste paper (over 130,000 tons of waste paper per year) be available to support ethanol development at that scale.

It may be possible, however, for municipalities to realize cost-effective operations in developing ethanol from mixed solid waste if the avoided costs of land-filling are included in the project. In this case, scale would be defined by the amount of waste to be disposed and the economics of public ownership would change the relationship of traditional variables.

(2) This report is based on information in the public domain. There is very likely an inherent bias in those developers known to public agencies. For the most part, those who seek counsel in public agencies are looking for financial assistance.

Therefore, there may be a bias in public information toward underfinanced and independent operators. It has been the history of ethanol development for corn, for instance, that, while Nebraska searched for means to develop an ethanol industry through independents and entrepreneurs, massive agribusiness corporations with facilities along the Mississippi River in Illinois developed plants which now account for 80% of the nation's ethanol production.

It may be the case, that those organizations most likely to move the production of ethanol from mixed waste paper out of the lab, will be those least known to government.

This is not to say that developers will not seek and acquire public subsidies such as those which underlie the ethanol from corn industry. But those subsidies have typically been acquired in the form of production guarantees and tax exemptions from the U.S. Congress, rather than as development grants.

(3) The influence of large corporations on government-funded ethanol research facilities introduces another bias into available information. Large corporations maximize the use of government research facilities to defray their research and development costs. Thus, their needs influence the scope and direction of research.

That is certainly one of the reasons why the major research models for ethanol development (at the Tennessee Valley Authority facility at Muscle Shoals, Mississippi and at the National Renewable Energy Laboratory at Golden, Colorado) emphasize large-scale production models. These models contain certain embedded assumptions about "economies of scale" which are only true for a defined set of production objectives.

Their outcomes, however, are frequently misinterpreted as defining an absolute economy of scale which rules out smaller scale facilities which may have a positive benefit/cost ratio under a different set of production assumptions. Economic Research Associates' was not able to locate, through conventional energy research facilities, a model for smaller facilities which might include the benefits of closed-loop generation suitable for municipal ownership and operation, for instance.

The Nebraska Energy Office could begin development of a model for small-scale closed-loop production of fuel ethanol from municipal solid waste. This model should include all variables involved in the community equation, including the full costs of landfilling waste and benefits of import substitution to the community.

(4) The arguments for mixed waste paper as a lower-cost feedstock for ethanol production are often based on an economic truism which is potentially fallacious.

The principle is often stated in some form similar to this excerpt from "The DOE/NREL Ethanol from Biomass Program," by C.E. Wyman, distributed by the National Renewable Energy Laboratory:

> Cellulosic biomass is much less expensive than corn or sugar because it has no food value.

It should be remembered, when considering a policy in support of ethanol development from mixed waste paper, that this is an inadequate statement of the economic principle which it purports to reflect. The statement is based on the concept of economic alternatives and is meant to reflect the notion that the price of a commodity is influenced by the value of its alternate uses.

It is certainly true that the price of corn or sugar is influenced by its value as a food. But it is also true that the value of waste paper will be influenced by any successful use of it in the energy chain.

Thus, the statement above is only partially and temporarily true. The complete principle of substitution would include at least three commodity prices:

1. Corn/sugar
2. Mixed waste paper
3. Oil

and many more accurate comparison statements could be made. For instance:

- -- Depending on events related to the value of oil, the price of corn or sugar as a fuel feedstock might exceed its value as a food.
- -- Depending on events related to municipal solid waste, the value of mixed waste paper might exceed the value of corn or sugar as a fuel feedstock.
- -- Depending on public or private policies, the price of any commodity may or may not reflect its true value.

Veterans of policy and program development during the 1973 and 1978 energy embargoes should be able to testify to the unexpected economic effects of major changes in a single significant commodity.

It is wise to remember that in recent times, it was not technological breakthrough or entrepreneurial risk-taking that propelled ethanol to economic viability. It was a political decision by the federal government that created a new value for ethanol through passage of the 1990 Clean Air Act Amendments.

The Nebraska Energy Office would be wise to avoid acceptance of misleading statements such as the one quoted above which riddle even purportedly expert publications. Rather, the Office should adopt a flexible policy which recognizes that price is a fleeting phenomenon and not a stable foundation for policy or program.

Findings and Recommendations for the Development of Other Potential Cellulosic Feedstocks

(5) If currently untested predictions of increased yields from bioengineering breakthroughs can be maintained at pilot and demonstration phases as they perform in the lab, other cellulose rich materials (such as corn stalks) may become commercially feasible feedstocks for ethanol.

There is currently no collection system for corn stalks; in fact, large public investments have been made in recent years to train farmers to leave harvest residue in the fields to conserve soil and reduce fuel use. Because investment requires stable production input and output markets, this is a barrier to ethanol production from corn stalks.

If the State of Nebraska determines that ethanol development from corn stalks is both possible and beneficial, it may wish to play a role in solving the problem of collecting corn residue as a feedstock. (At least one knowledgeable engineer has suggested that farm equipment could be modified to harvest stalks at the same time as grain.) A University of Nebraska-Lincoln study is currently addressing this subject and will be available by June, 1993. Preliminary estimates indicate that a 70-mile radius around Kearney, Nebraska may have the greatest potential for such a venture.

(6) Some experts have suggested that the U.S. Department of Energy (DOE) will focus on research into fast-growing cellulose crops--probably trees--for ethanol development. As with corn, while this might not make complete sense as an energy program, it may offer Nebraska crop diversification opportunities.

Tree crops have been proposed to the Nebraska Energy Office in the past for development in the Omaha area as part of comprehensive waste management. In those proposals, use of the wood product was problematic. Recent promising developments in ethanol from cellulose could alter the feasibility of this proposal. As with mixed waste paper, ethanol development economics change quickly and significantly when benefits that can only be derived by the public sector are part of the project yield.

The Nebraska Energy Office should stay alert to DOE and USDA to crop experimentation developments for possible pilot-project siting in Nebraska.

* * * * *

II. ETHANOL INDUSTRY OVERVIEW

History of Fuel Ethanol Production

Interest in alcohol fuels began in the early 1900's. With low commodity prices for grains and the advent of the automobile, advocates were hopeful that alcohol based fuels would soon create vast new markets for grains. But with the development of U.S. oil fields producing cheap gasoline, the idea never got off the ground.

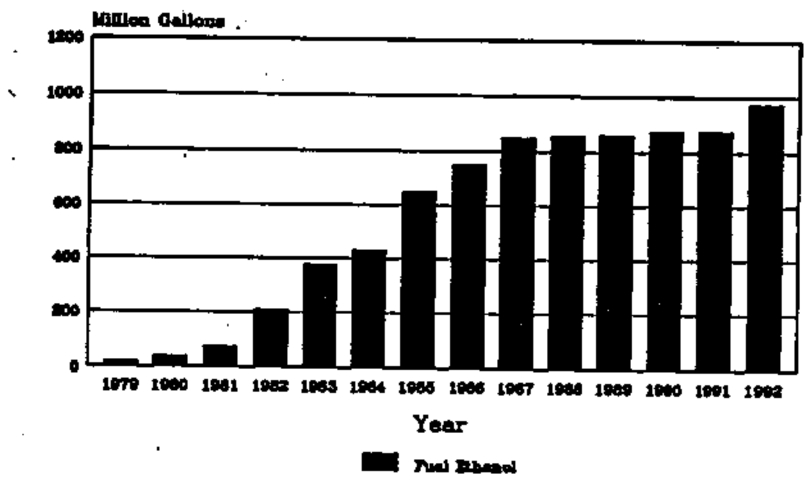
The energy crisis and oil shortage of the early to mid 1970's again stimulated interest in alcohol based fuels, especially fuel ethanol, as a solution to reliance on petroleum based gasoline that was in large part imported. It was also viewed as a potential market for surplus grain production. In the early 1970's, the State of Nebraska passed landmark legislation that established a commission to promote fuel ethanol usage and also set a precedent by providing a $0.03 per gallon gasoline tax exemption for the use of fuel ethanol. Other midwestern states soon followed with their own incentive and marketing programs, and government subsidization of the ethanol industry began.(1)

Current Status

Commercial ethanol production began and has expanded over the last decade for many reasons, including a destabilized petroleum industry, grain surpluses, the need to increase our domestic energy independence, and public sector subsidies. Production has grown steadily, and by 1992, the U.S. was producing over 975 million gallons of fuel ethanol. This is nearly a 25 fold increase from the 40 million gallons that were produced in 1980. Graph 1 shows U.S. fuel ethanol production in recent years.

GRAPH 1.

U.S. ETHANOL PRODUCTION 1979-1992



Source: Information Resources, Inc.

Most of U.S. ethanol production occurs in very large facilities. In 1990, the four largest plants, all owned by Archer-Daniels-Midland (ADM), the multinational grain merchandiser, accounted for over 70 percent of total operating production capacity (+700 million gallons). All of these plants are located along the northern reaches of the Mississippi River in Illinois and Iowa.(2) The vast majority of the ethanol industry is comprised of approximately 60 plants nationwide in over 20 states. Of these plants, only about one-half use corn as a feedstock, but 85-90% of ethanol production is from corn-utilization plants. The remaining plants use either other grains, such as wheat, milo, or barely, or waste materials, such as food processing wastes like cheese whey or peelings from potato-processing plants.

Corn is the main feedstock used for ethanol production, accounting for 86.0% of the total in plants over 500,000 gallons per year in 1987. Table 1 shows a breakdown of ethanol production feedstocks.

TABLE 1

USAGE OF FEEDSTOCKS IN ETHANOL PRODUCTION - 1987
(Plants over 500,000 gallons per year)

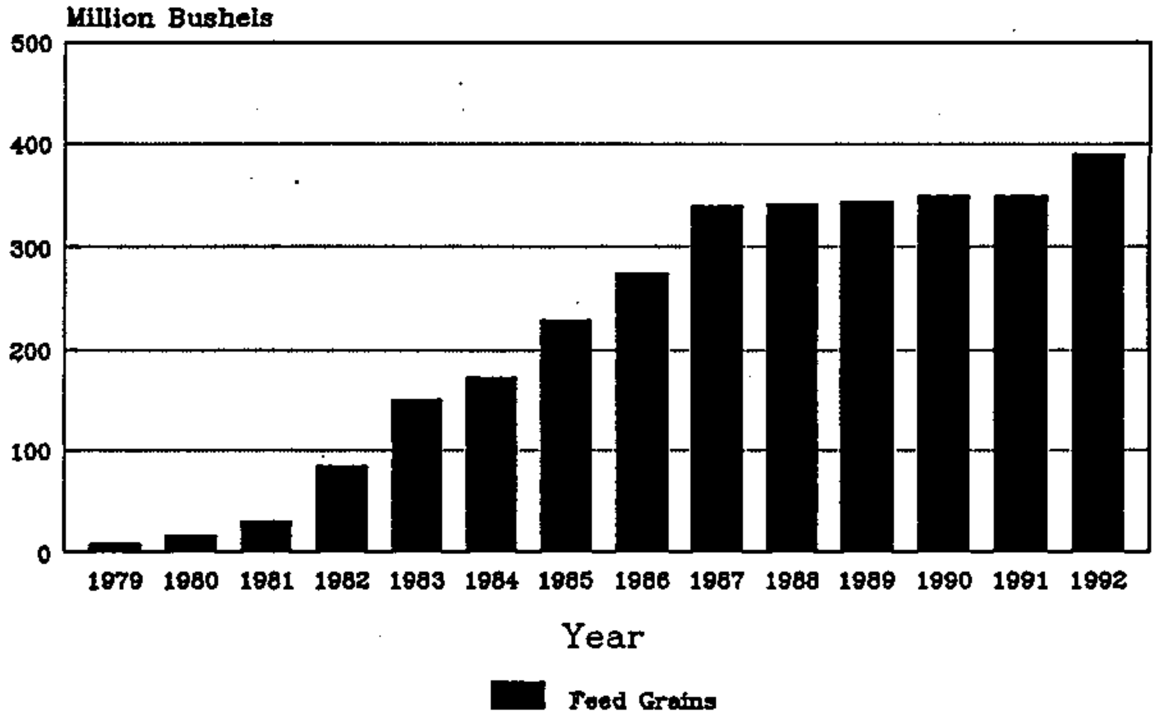
Corn	86.0%
Wheat, Barley and Milo	5.0%
Miscellaneous Feedstocks	4.0%
Agricultural or Industrial Waste	4.0% *
Molasses	1.0%
	100.0%

* includes dehydration only facilities
Source: "Fuel Ethanol Cost-Effectiveness Study", USDA, 1987.

Sources at the U.S. Department of Agriculture estimate that a much higher percentage of ethanol is currently being produced from corn (+90.0%) than the 1987 estimates indicate.(3)

Grain utilization for ethanol production has grown dramatically as ethanol production has risen. Usage has increased over 30% per year in the last 12 years, from a total of 16 million bushels in 1980 to over 390 million bushels in 1992 (4). Graph 2 shows grain utilization for ethanol production.

GRAPH 2. GRAIN UTILIZATION FOR U.S. ETHANOL PRODUCTION 1979-1992



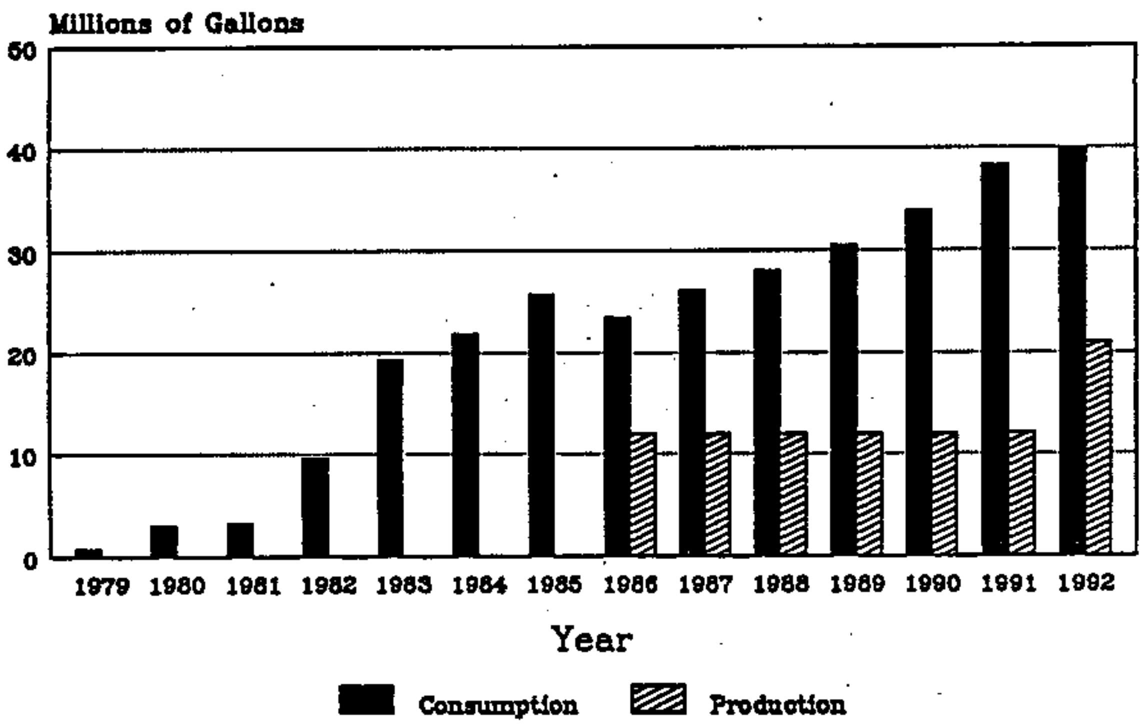
Source: Information Resources Inc.

Ethanol in Nebraska

Nebraska, because of long-standing consumption incentives provided by state government, has long been a leader in consumption of ethanol fuels. Production of ethanol is only now beginning to expand, and as a result, Nebraska has always been a net importer of ethanol fuels. Graph 3 shows ethanol consumption and production in Nebraska from 1979 to 1992.

GRAPH 3. NEBRASKA ETHANOL

Consumption & Production 1979-1992



Source: Nebraska Gasohol Committee

Public Policy

Federal

Ethanol has long been provided a number of production, consumption and capital cost subsidies to encourage the growth and development of the industry. Beginning in 1978, a series of public policies to promote the ethanol industry have been implemented. Current policy, contained in the 1990 *Miscellaneous Tax and Budget Reconciliation Act* extended the excise tax exemption for gasoline blended with 10% ethanol (gasohol) through December 31, 2000. This excise tax exemption allows gasohol to be exempt from 5.4 cents of the 14.1 cents of federal gasoline excise tax. This is equivalent to a 54 cent subsidy per gallon of ethanol produced.

The *Act* also established a ten cent per gallon production tax credit on the first 15 million gallons per year of ethanol produced at facilities with a capacity less than 30 million gallons per year.

Capital construction subsidies for ethanol production facilities, either in the form of guaranteed loans or direct payments in return for shares in the facilities, are also available under current Federal statute from both the U.S. Department of Agriculture and the U.S. Department of Energy. As of 1989, Federally financed plants constituted about 25 percent of total industry capacity. Most of these plants were built with Federally guaranteed loans and are relatively small, producing under 40 million gallons per year.

1992 also saw a policy precedent as ethanol was awarded a 1.0 pound exemption for Reid vapor pressure (Rvp) to allow the oxygenate to continue to be included as a possible alternative fuel within the *Clean Air Act*. This Rvp waiver is still being debated and may be changed under the Clinton administration.

State of Nebraska

Nebraska has long been at the forefront of promotion and advancement within the ethanol industry. In 1971, Nebraska passed the first ethanol tax exemption legislation, exempting 10% ethanol blended fuels from three cents of the state gasoline excise tax (30 cents per gallon of ethanol) and creating the Nebraska Ethanol Development Board. In 1978 that exemption was increased to five cents per gallon.

Nebraska has stayed very active in the promotion and growth of the ethanol industry by supplying a number of tax incentives to promote both production and consumption and to defer capital costs by being able to invest in up to 49% of plant costs.

In 1990, the Nebraska legislature reduced the State excise tax exemption from three to two cents per gallon and set an expiration date for the tax exemption of December 31, 1992. In addition, the legislature established a producer incentive of 20 cents per gallon of ethanol produced in the state at facilities larger than two million gallons but smaller than 25 million gallons of annual production. These production incentives are due to expire December 31, 1997.

In 1992, the legislature again took action to try to further develop the ethanol industry in the state. The 1992 *Ethanol Production Incentive Act* allowed the excise tax exemption of two cents per gallon to expire. With this legislation, Nebraska has chosen to emphasize ethanol production instead of consumption. Under the *Act*, the following production credits apply:

> Nebraska law (Section 66-1326) provides production credits based on volume of production but with some requirements for development of capacity.
>
> The Law provides a tax credit of 20-cents per gallon to producers who ferment, distill and dehydrate ethanol in Nebraska. The credit is available only to producers of more than two million gallons a year and applies only to 25 million gallons per year, subject to the following conditions:
>
> -- A facility in production before January 1, 1992, must double the capacity it had on that date or its credit will cease on July 1, 1994; in addition, the plant must have been producing at 25% of its capacity on January 1, 1992 to earn the credit which terminates, under current law, 60 months later, on December 31, 1997.

-- A facility not in production on January 1, 1992, must come into production of at least 25% of capacity before December 31, 1995 to claim the credit which then extends for 60 months but expires, under current law, on December 31, 2000.

Impacts of Nebraska Policy Changes

Significant changes are expected for the ethanol industry in Nebraska because of these new state laws; the two most significant are a decrease in demand for ethanol blended fuels in Nebraska and an increase in production.

Because of the expiration of the motor fuels tax credit on December 31, 1992, the Nebraska Gasohol Committee estimates that consumption of ethanol blended fuels in Nebraska will decrease slightly.(5)

Increased subsidies for ethanol production is predicted to increase from 1992 production of over 22 million gallons to 155 million gallons by 1996, nearly a 700% increase. (Table 2 lists these production increase projections.)

TABLE 2

PROJECTED PRODUCTION INCREASES FOR NEBRASKA ETHANOL INDUSTRY

	CURRENT PRODUCTION (1992)	PROJECTED PRODUCTION (1993-94)	PROJECTED PRODUCTION (1995+)	PERCENT INCREASE (1992-1995+)
CHIEF ETHANOL HASTINGS	13,000,000	29,000,000	29,000,000	223.08%
MINNESOTA CORN PROCESSORS COLUMBUS	9,250,000	37,000,000	37,000,000	400.00%
NEBRASKA NUTRIENTS SUTHERLAND	0	14,500,000	14,500,000	--
CARGILL ETHANOL BLAIR	0	0	50,000,000	--
OTHER CONSTRUCTION	0	25,000,000	25,000,000	--
PRODUCTION TOTALS	22,250,000	105,500,000	155,500,000	623.08%

Notes: Chief Ethanol to complete expansion May 1, 1993.
Minnesota Corn Processors plant began production October 1, 1992.
Nebraska Nutrients plant to begin production January 1, 1993.
Cargill ethanol plant to begin production January 1, 1995.
Other construction (one plant) anticipated to begin production by January 1, 1994.

Source: Estimates provided by Mr. Steve Sorum, Nebraska Gasohol Committee, Lincoln, Nebraska, November, 1992.

Ethanol Fuel End Markets

Impacts of the 1990 *Clean Air Act* Amendments

Passed by Congress in 1990, the *Clean Air Act* Amendments will likely be the driving governmental action behind the increased use of oxygenated and reformulated fuels, mainly because of mandates for carbon monoxide (CO) and ozone levels.

Title II of the amendments (otherwise known as the *National Emission Standards Act*) sets forth the new laws dealing with motor vehicle emissions. Title II addresses the problem of emissions in two ways. First, it requires the provision of "oxygenated" gasoline, gasoline designed to reduce carbon monoxide emissions. It also requires "reformulated" gasoline--gasolines designed to reduce ozone--in all non-attainment areas in the United States.

Non-attainment areas are defined as those areas not meeting certain air quality standards, in this case for carbon monoxide and ozone emissions for motor vehicles. Non-attainment areas are classified according to pollutant type and severity of the pollution problem. Non-attainment areas with the most serious problems are then given the greatest number of years to comply with the Title II provisions. For instance, the Los Angeles basin is given 15-20 years to fully comply with the Title II emission mandates.(6)

Thirty-nine cities nationwide must sell oxygenated fuel blends during the winter of 1992-1993 in order to achieve mandated attainment levels for carbon monoxide (CO) and ozone. Cities which must comply located in the midwest include several cities along the front range of Colorado including Denver, Minneapolis-St. Paul, and St. Louis, Missouri. (Table 3 located on page 19 lists these cities).

Title II appears to have the "teeth" in it and the deadlines for action are soon enough that it may have some very positive effects on reducing air pollution. But the problem with Title II, although it will reduce emissions per motor vehicle, is that it does not address the dramatic increases in the number of cars and trucks on the road and the increasing number of vehicle miles traveled.

TABLE 3

1992-1993 CARBON MONOXIDE NON-ATTAINMENT AREAS

(Marketers must sell either Ethanol blends at a 10% mix or MTBE at a 15% mix)

NEBRASKA & SURROUNDING BORDER STATES
Colorado Springs, CO
Denver-Boulder, CO
Fort Collins, CO
St. Louis, MO-IL

OTHER MIDWESTERN STATES
Minneapolis-St.Paul, MN
Oklahoma City, OK
Winnebago, CO, Oshkosh, WI

MIDEASTERN STATES
Cleveland, OH
Steubenville-Weirton, OH-WV
Memphis, TN-AR-MS

EAST COAST
Hartford, CT
New York, NY-NJ-CT
Boston, MA
Baltimore, MD
Manchester, NH
Washington D.C.-MD-VA

SOUTHEASTERN STATES
Raleigh-Durham, NC
Greensboro-Winston Salem, NC

SOUTH/SOUTHWESTERN STATES
Phoenix, AZ
Albuquerque, NM
Las Vegas, NV
Reno, NV
El Paso, TX

NORTH/NORTHWESTERN STATES
Great Falls, MT
Missoula, CO, MT
Klamouth, CO
Grecley, CO
Provo-Orem, UT
Salt Lake City-Ogden, UT

FAR WESTERN STATES
Chico, CA
Fresno, CA
Los Angeles, CA
Modesto, CA
Sacramento, CA
San Diego, CA
San Francisco-Oakland, CA
Josephine, CO, OR (Grants Pass)
Medford, OR
Portland-Vancouver, OR-WA
Seattle-Tacoma, WA
Spokane, WA
Yakima, WA

The number of vehicle miles traveled doubled between 1970 to 1990, increasing at a rate of approximately 3.5% per year during the time frame. In comparison, the population of the United States grew only about 1.0% per year (about 22.5% over the whole period). The Environmental Protection Agency (EPA) has recognized this problem:

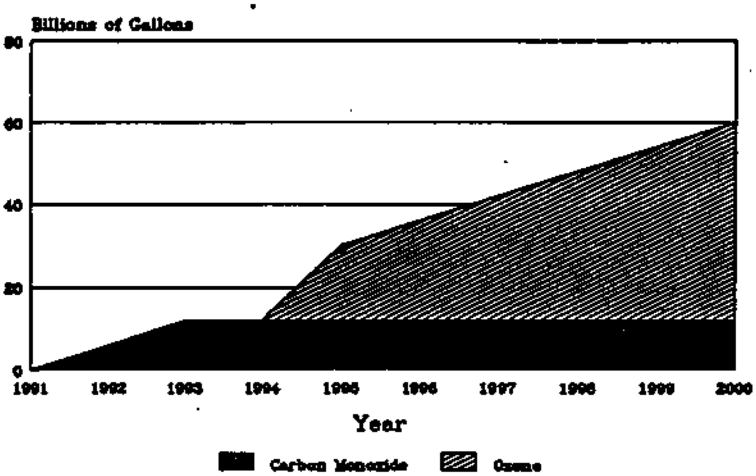
> "It is now clear that technological improvements to the motor vehicle are being offset by the growth in the number and usage of vehicles. Not only does high growth directly increase emissions, it leads to more congestion, which further increases emissions. Transportation measures to reduce this growth were given a strong push throughout the country in the late 1970's, but they were rolled back in the early 1980's. They should be tried again."(7)

It is estimated that over 6 billion gallons will be affected during the winter of 1992-1993. This amounts to only about 5% of the total U.S. gasoline consumption of about 115 billion gallons per year.

Increased Demand for Oxygenated Fuels

The Clean Fuels Development Coalition has estimated that 60 billion gallons of gasoline will be regulated annually under the Clean Air Act by the year 2000. Ethanol industry advocates believe that ethanol could capture up to 30.0% of this new market potential (18 billion gallons annually by 2000--1.8 billion gallons of ethanol if blended at 10%).(8) Graph 4 shows total gallons of gasoline that will need to be reformulated under the 1990 *Clean Air Act* Amendments.

GRAPH 4.
TOTAL GALLONS OF GASOLINE
TO BE REFORMULATED – CLEAN AIR ACT



Source: Clean Fuels Dev. Coalition, 1991

Increased Regional Demand for Oxygenated Fuels

The American Coalition for Ethanol, a North Dakota based advocacy group of midwestern ethanol producers, has estimated future increases in production and consumption of ethanol fuels for several midwestern states surrounding Nebraska. Table 4 shows those estimates.

TABLE 4

REGIONAL ETHANOL PRODUCTION AND CONSUMPTION ESTIMATES

	CURRENT PRODUCTION (1992)	PROJECTED PRODUCTION (1993-95)	PROJECTED PRODUCTION (AFTER 1995)	PERCENT INCREASE (1992 TO 1995+)
MINNESOTA	26,000,000	73,000,000	157,000,000	603.85%
NORTH DAKOTA	23,500,000	43,000,000	75,000,000	319.15%
SOUTH DAKOTA	2,500,000	6,500,000	10,500,000	420.00%
COLORADO	NA	NA	NA	NA
PRODUCTION TOTALS	52,000,000	122,500,000	242,500,000	466.35%

	SALES (1991)	PROJECTED SALES (1997)*	PERCENT INCREASE (1992-1997)
MINNESOTA	45,159,200	139,315,020	308.50%
NORTH DAKOTA	5,335,600	15,520,840	290.89%
SOUTH DAKOTA	13,624,900	27,233,760	199.88%
COLORADO	10,084,400	65,780,960	652.30%
SALES TOTALS	74,204,100	247,850,580	334.01%

* Based upon 40% market shares in Colorado and North Dakota and 60% market shares in Minnesota and South Dakota.

As the estimates contained in Table 4 show, production will likely rise faster than consumption in the near-term for the region.

Therefore, market entry opportunities are at hand, but they will probably have to be outside of these middle-border states.

CONCLUSIONS

Subsidies continue to be one of the most important components in the ethanol production equation. Without federal and state subsidies, it is unlikely that ethanol production would be occurring at the rate that it currently is.

The *Clean Air Act* will likely have dramatic impacts upon the ethanol industry. With predictions that domestic consumption of ethanol could nearly double within the next decade, the ethanol industry may finally be ready to break through and be a leading player in the oxygenated fuels market.

III. SOLID WASTE MANAGEMENT / MIXED WASTE PAPER OVERVIEW

Increasing generation and decreasing disposal options for solid waste in the United States has put tremendous pressure on the existing solid waste management industry.

Landfilling, which has traditionally been the favored disposal option, is projected to become much more costly because of recent policy changes at both the national and state levels which will more accurately reflect the full costs of landfilling.

Federal Policy Overview

In 1991, Congress passed comprehensive integrated solid waste management legislation intended to address all facets of the problem. This legislation is commonly referred to as EPA "*Subtitle D*" regulations.

Subtitle D went far beyond any existing regulatory guidelines to make legislators and administrators alike address the full costs of existing methods (specifically landfilling) and to assess all options for use of solid waste. The legislation set forth the following hierarchy to deal with solid waste:

1. Volume reduction at the source;
2. Recycling, reuse and vegetative waste composting;
3. Incineration with energy resource recovery;
4. Incineration for volume reduction;
5. and, land disposal.

Projected impacts of *Subtitle D* are many. Likely, the greatest impact will be the increase in tipping fees paid to landfills to dispose of waste. The EPA has estimated that the average nationwide tipping fee is about $42 per ton, a substantial increase from just a few years ago.(9) It has also been estimated that construction, maintenance and closure of landfills will range between $400,000 to $800,000 per acre in the near future.(10)

Nebraska Policy Overview

Under *Subtitle D* all states are mandated to comply with all solid waste management guidelines contained in the statute. This includes using full-cost methods for evaluating disposal options, generally complying with the hierarchy of criteria, and closure of substandard landfills.

In 1992, the Nebraska Legislature passed the *Nebraska Integrated Solid Waste Management Act*. The most important segments of the *Act* relating to solid waste management include establishment of a hierarchy of criteria, target dates for volume reduction, and closure of substandard landfills. The hierarchy set forth within Nebraska statute is:

1. Volume reduction at the source;

2. Recycling, reuse and vegetative waste composting;

3. Land disposal;

4. Incineration with energy resource recovery;

5. and, Incineration for volume reduction.

Waste reduction and recycling goals are also established within the statute. They are:

> "The integrated solid waste management plan shall provide for a local waste reduction and recycling program. If technically and economically feasible, the volume of materials disposed of in landfills (shall be reduced by):

Date	Percent Reduction
July 1, 1996	25.0%
July 1, 1999	40.0%
July 1, 2002	50.0%

(Baseline date for reduction - July 1, 1994)

Current Status

Municipal solid waste (MSW) has become an increasingly troublesome problem. In 1990, according the U.S. Environmental Protection Agency (EPA) 1992 Characterization of Municipal Solid Waste, total MSW generated in 1990 equalled over 195 million tons (about 4.3 pounds per day per person). It is also projected that this amount will increase by 0.34% per year indefinitely given current solid waste management practices.(11)

The mixed waste paper component of the solid waste stream is by far the largest single segment. Again, according to the EPA characterization, all paper and paperboard generated accounted for over 73 million tons in 1990, or about 37.5% (1.6 pounds/day/person).

Current Status in Nebraska

It was estimated that over 1.8 Million tons per year (TPY) of MSW were generated in Nebraska in 1990.(12)

For the purposes of this study, all paper generation in east central Nebraska was to be evaluated. Finding the exact amount of waste paper generated in this study area is a difficult task and one beyond the scope of this project. Therefore, we have determined the approximate amounts generated, recycled, and available and are presenting the data in the following ranges.

TABLE 5

ESTIMATED WASTE PAPER AND PAPERBOARD - EAST CENTRAL NEBRASKA

	TONS PER YEAR	
	High	Low
TOTAL GENERATED	475,000	350,000
TOTAL RECYCLED	100,000	75,000
TOTAL LANDFILLED	400,000	250,000

There exist two areas of high concentration of waste paper in the east central Nebraska region; Omaha and Lincoln.

As the two largest metropolitan areas in the state and the home to state government, a large university system, and a significant concentration of both insurance and telemarketing firms, these two communities likely produce more waste paper per capita than national averages. [Note: If the national average of 1.6 pounds/day/person was applied to the approximate population of east-central Nebraska, these 800,000 people would produce 233,600 tons of MWP per year - well below the estimates we have obtained within this study].

WASTE PAPER IN NEBRASKA METROPOLITAN AREAS

The City of Lincoln and Lancaster County conducted a comprehensive waste characterization study in 1990. The relevant highlights for the study concerning waste paper appear below:

TABLE 6

1990 LANCASTER COUNTY WASTE PAPER DATA

	Paper Type	Annual Tons (1990)
TOTAL GENERATED		
	Mixed Paper	71,268
	Paperboard & Corrugated	38,776
	Newsprint	16,896
	High Grade Paper	11,795
		138,735
TOTAL RECOVERED		
	Mixed Paper	10,352
	Paperboard & Corrugated	7,720
	Newsprint	3,228
	High Grade Paper	5,002
		26,302
	TOTAL LANDFILLED	112,433

Source: Lincoln/Lancaster County Recycling Office *"1990 Solid Waste Characterization Study"*.

The City of Omaha is a member of the Metropolitan Area Planning Agency (MAPA) which comprises all of Douglas, Sarpy and Washington counties in Nebraska, and Mills and Pottawattamie counties in Iowa.

The most recent waste characterization data available for the MAPA area or the City of Omaha is the "MAPA Regional Solid Waste Management Report and Recommendations" published in early 1985. Data contained in the report is all from calendar year 1983.

In order to try to determine quantities available for the MAPA, we have updated the 1983 data to 1992 estimations by assuming a 0.34% increase in MSW generation each year. These 1992 range of estimations for the Nebraska portion of the MAPA area are:

TABLE 7

MAPA ESTIMATED WASTE PAPER CONDITIONS - 1992

	Paper Type	Annual Tons (1992) High	Annual Tons (1992) Low
TOTAL GENERATED	All	275,000	200,000
TOTAL RECOVERED			
	Mixed Paper	6,000	2,000
	Paperboard & Corrugated	40,000	30,000
	Newsprint	16,000	8,000
	High Grade Paper	13,000	10,000
	Subtotals	75,000	50,000
	TOTAL LANDFILLED	225,000	125,000

Note: Data derived by conservative estimations by Economic Research Associates and confirmed by personal communication with Mr. Bruce Ehrich, MAPA Environmental Planner, Jan. 1993.

MAPA will begin a waste characterization study in March, 1993 and should be completed by summer of 1994. It is suggested that data be substituted for this data when it becomes available.(13)

Current Markets for Waste Paper

Nebraska currently does not have a mill to recycle paper products. The closest recycling mill for paper is located in Kansas City, Kansas. Most Nebraska wastepaper is transported to either Chicago or the Pacific Northwest for processing.

Small scale firms do exist in Nebraska that use waste paper for productive purposes. Parco Insulation Inc., located in Norfolk, is the largest of these firms, and currently uses approximately 12,000-15,000 tons of newspaper per year to produce insulation.(14) Cellulose Insulation of Nebraska, a Papillion (Omaha) based recycler, also processes a few thousand tons of newspaper annually to produce insulation.

The City of Omaha and its contractor Waste Management Inc. currently have a contract with Weyerhauser Paper, located in Seattle, Washington for all of its newspaper recovered within the residential recycling program. Approximately 4,500 tons per year of newspaper are currently being shipped under this contract.(15)

The City of Lincoln does not currently have a coordinated effort for waste paper recycling. Current activities include a city-wide drop-off collection program administered by the City of Lincoln, a number of private curbside recyclers, and a network of private recyclers led by Dennis Paper, Inc. of Lincoln, who contract with commercial businesses to collect their waste paper.(16)

Both the University of Nebraska-Lincoln and the State of Nebraska currently contract with Dennis Paper, Inc. to pick up their waste paper. Approximately 150 tons per year are currently being picked up from the State of Nebraska offices in Lincoln.(17)

Waste Paper Market Prices

Waste paper market prices are very volatile and make drastic swings for many grades of waste paper. Current market values range between $0 to $150 per ton. Following is a table listing ranges of approximate market values for various waste paper stocks as of January, 1993:

WASTE PAPER TYPE	PRICE RANGE ($/Ton)
Mixed Paper	$5-$15
Newspaper	$15-$25
Corrugated Cardboard	$20-$30
Mixed Office Paper	$40-$100
High Grade Office Paper	$80-$150

Note: These prices reflect estimations by east-central Nebraska recyclers of prices they receive from mills.

These prices vary considerably not only because of market forces but because of quality, quantity and type of waste paper sold. For instance, there are currently over 70 grades of paper.

Also of note is that it has been estimated by local recyclers that it normally costs between $15-$30 per ton to recover and bail waste paper from the waste stream.

Alternative Uses for Waste Paper

The University of Nebraska-Lincoln Center for Infrastructure Research completed a recycling market development study for east-central Nebraska in 1990. The study specifically identified two potential markets for waste paper in east-central Nebraska: (1) using shredded waste paper as animal bedding; and (2) producing hydromulch, which is shredded waste paper mixed with water and fertilizer, used as ground cover for newly planted grass. We have also chosen to include a third option, (3) the production of cellulosic insulation from waste paper, in this market analysis. The following paragraphs summarize market potentials for these wastepaper derived products.

Animal Bedding

The UN-L report on using wastepaper as animal bedding specifically evaluated using only old newspaper. Old newspaper was chosen for two specific reasons: (1) Old newspaper has a much higher absorbency than other wastepaper products; and (2) it is easily composted when saturated.

The animal bedding study reviewed both data from sources nationwide on the affects of using waste paper as animal bedding (such as toxicity) and potential markets for the product in east-central Nebraska.

The report concluded that no negative affects have been found because of the use of waste paper for bedding (no harmful affects on either meat or milk). The report also concluded that the potential uses for animal bedding far exceed the waste paper production in east-central Nebraska, and therefore all waste paper shredded for this purpose could be used in local markets if market factors were appropriate.

The report also stated that shredded waste paper was ten times more absorbent than straw for animal bedding, and it could be purchased, processed and transported to end users for between $35 to $70 per ton.

Hydromulch

Hydromulch, which is a cellulose product made from shredded waste paper or wood pulp that is mixed with water and fertilizer and sprayed onto the landscape with or on top of grass seed to aid in germination and moisture retention, is another alternative use for waste paper evaluated by the UN-L report. According to area landscapers, hydromulch is not a new product. What is new is the idea of using waste paper products instead of straw as the hydromulch feedstock.

Common specifications require that about 1700 pounds of hydromulch be applied per acre to be seeded. Hydromulch is used by spraying the mixture onto bareground where the mixture will form a protective crust similar to paper mache over and around the new seed. The crust will slowly disappear as the area is irrigated.

Several trials have been completed in east-central Nebraska with these results. It was determined that hydromulch from waste paper costs about $200 more per acre than using straw as the feedstock, but the labor involved in processing and applying waste paper hydromulch is less. Waste paper hydromulch proved more suitable for areas with higher wind velocities (airports and roadsides) because it withstands higher winds and does not create as much dust and debris as straw based hydromulch does.

Total east-central Nebraska market potential for waste paper hydromulch was not evaluated as part of the project.

Cellulosic Insulation

Currently, the only value-added processing of waste paper in east-central Nebraska is the production of cellulosic insulation from old newspaper. Two firms are currently engaged in this business enterprise; Parco Insulation of Norfolk and Cellulose Insulation of Nebraska, located in Papillion (Omaha). These two firms combined process 20,000 to 25,000 tons per year of old newspaper. These firms currently get less than one-half of their newspaper feedstock from Nebraska sources.

Cellulose insulation made from old newspaper has advantages over traditional fiberglass insulation. Cellulose insulation has a higher "R" factor (insulating factor), about 3.65-3.70/inch, than fiberglass insulation, which has an "R" factor of about 3.30/inch. Cellulose insulation is also made from a reused product versus fiberglass which is made out of a petroleum derivative.(18)

Cellulosic insulation currently only accounts for about 5% of the total insulation market nationally, and is not anticipated to grow significantly in the near future.

Future market potential for cellulosic insulation in east-central Nebraska is not projected to increase significantly in the near future. Therefore, it is doubtful that this market segment will use much more waste paper than it currently does.

Analysis of Alternatives

All three of these examples of alternative markets for wastepaper specifically use old newspaper, only one segment of the wastepaper stream. Very few other local markets have been established. It is likely that both high-grade paper and corrugated cardboard will be transported and recycled given current market prices, but other mixed wastepaper (magazines, junk mail, etc.) will likely not be recycled given current market prices or potential uses. This segment of low grade mixed waste paper currently has almost no market value or viable alternative uses. This segment of mixed waste paper could potentially be a very low cost feedstock for the production of cellulosic based ethanol.

CONCLUSIONS

This section has evaluated current conditions for waste paper quantities and the likely destination (recovered or landfilled) for various grades of wastepaper in east-central Nebraska.

This section demonstrates that it is unlikely that Nebraska will meet its specified waste reduction goals if advances are not made in the recovery of waste paper from the wastestream. This section also demonstrates there is still a tremendous amount of wastepaper being landfilled in east-central Nebraska and that there is room for market entry into either traditional or new technologies for recovering and processing waste paper in east central Nebraska.

IV. ETHANOL PRODUCTION TECHNOLOGY

Ethanol is merely alcohol which can be produced from organic material that can be broken down to sugar molecules.

Just as edible sugars are a source of stored energy for human bodies, so are chemical sugars a source of stored energy for machinery. Conversion from chemical sugars to alcohol is just a way of converting stored energy from one form to another.

Today in the United States, most ethanol is produced from corn. While corn is a rich feedstock for ethanol, it is used primarily because it is heavily subsidized both in production and in use.

A. CURRENT ETHANOL PRODUCTION TECHNOLOGY AND COSTS

Ethanol is currently produced by converting grain crops, such as corn, which contain substantial amounts of starch and fermentable sugar, to alcohol. This process produces ethyl alcohol (ethanol), which is then blended with gasoline to produce gasohol. The ethanol serves as a gasoline extender and octane enhancer.

The basic steps of processing corn into ethanol are milling, separating starch, converting to sugars, fermenting, distilling and dehydrating. The process also generates by-products such as carbon dioxide, corn oil and protein feed supplements.

Two processing technologies are currently used for converting grain to ethanol: dry and wet grain milling. Dry milling is a variant of the more traditional technology of producing grain alcohol, while wet milling is a refinement of the corn to starch technology. Both of these processes are very similar, with the exception of the initial separation process. (Please see diagrams of dry and wet milling processes located on pages 33 and 34).

In the dry milling process, the grain first is ground into a meal consistency, then slurried with water and cooked. This cooking process produces complex sugars which then help to facilitate the conversion and fermentation processes using yeast. The resulting "beer" mixture is then distilled to produce hydrous ethanol, and then further processed to produce anhydrous ethanol.

The wet milling process is very similar to the dry milling process with the exception of the initial steps. In the wet milling process, the first step is the soaking of the grain in a water and sulfur dioxide mixture, and then the germ component of the kernel is separated. The remaining slurry is then screened to remove fibers, and the remaining starch is saccharified, fermented and distilled in the same manner as the dry milling process. Wet milling facilities can also be outfitted to allow for production of either ethanol or HFCS (high-fructose corn syrup).

Ethanol yields for both processes are generally very close, ranging from 2.50 to 2.65 gallons of undenatured fuel-grade ethanol per bushel of grain processed.(19)

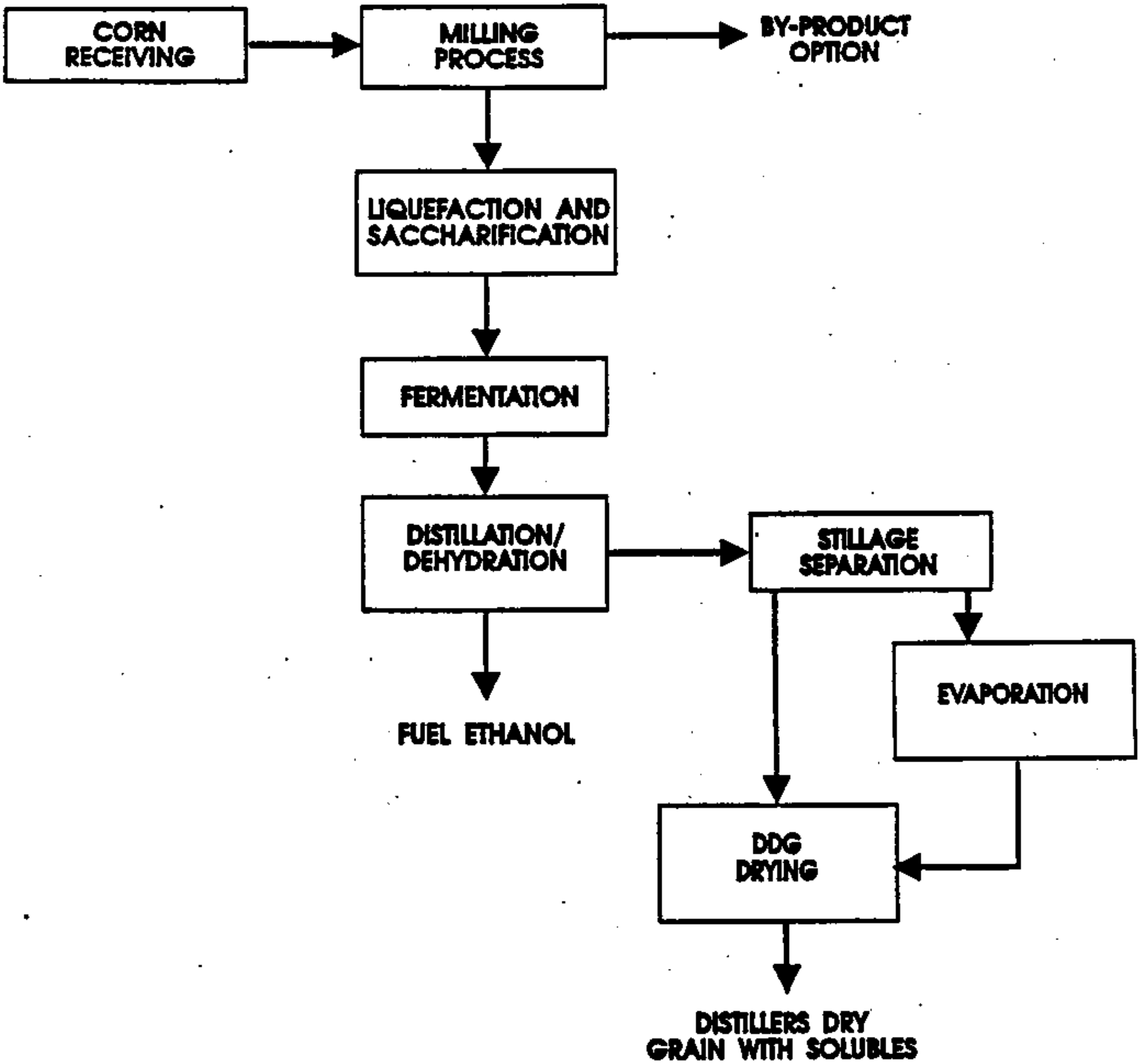
The greatest variances between the two processes are the initial investment costs and the by-products produced from each respective process. Wet milling facilities normally require a much greater initial capital investment than similarly sized dry milling facilities because of the extra steps during the initial processing. But a wet milling facility will have the capability of flexible production between ethanol or HFCS and of producing by-products of much higher value than a dry milling facility. In most cases, wet milling processes have proven to be slightly more profitable than dry milling processes, depending upon prevailing market prices, the cost of capital and the prices received for resulting by-products.

By-products Produced

In addition to ethanol, both milling processes generate by-products. Dry milling will produce two main by-products during the processing stages. Sixteen and one-half to 17.5 pounds of DDGS (distillers dried grains with solubles) are generated for every bushel of corn processed. DDGS is commonly used as a protein animal feed and is a result of the beer distillation phase. Carbon dioxide (CO_2) is also generated during the production process. It is generated in similar quantities to DDGS, and is used in food processing, dry ice production, and tertiary recovery of oil.(20)

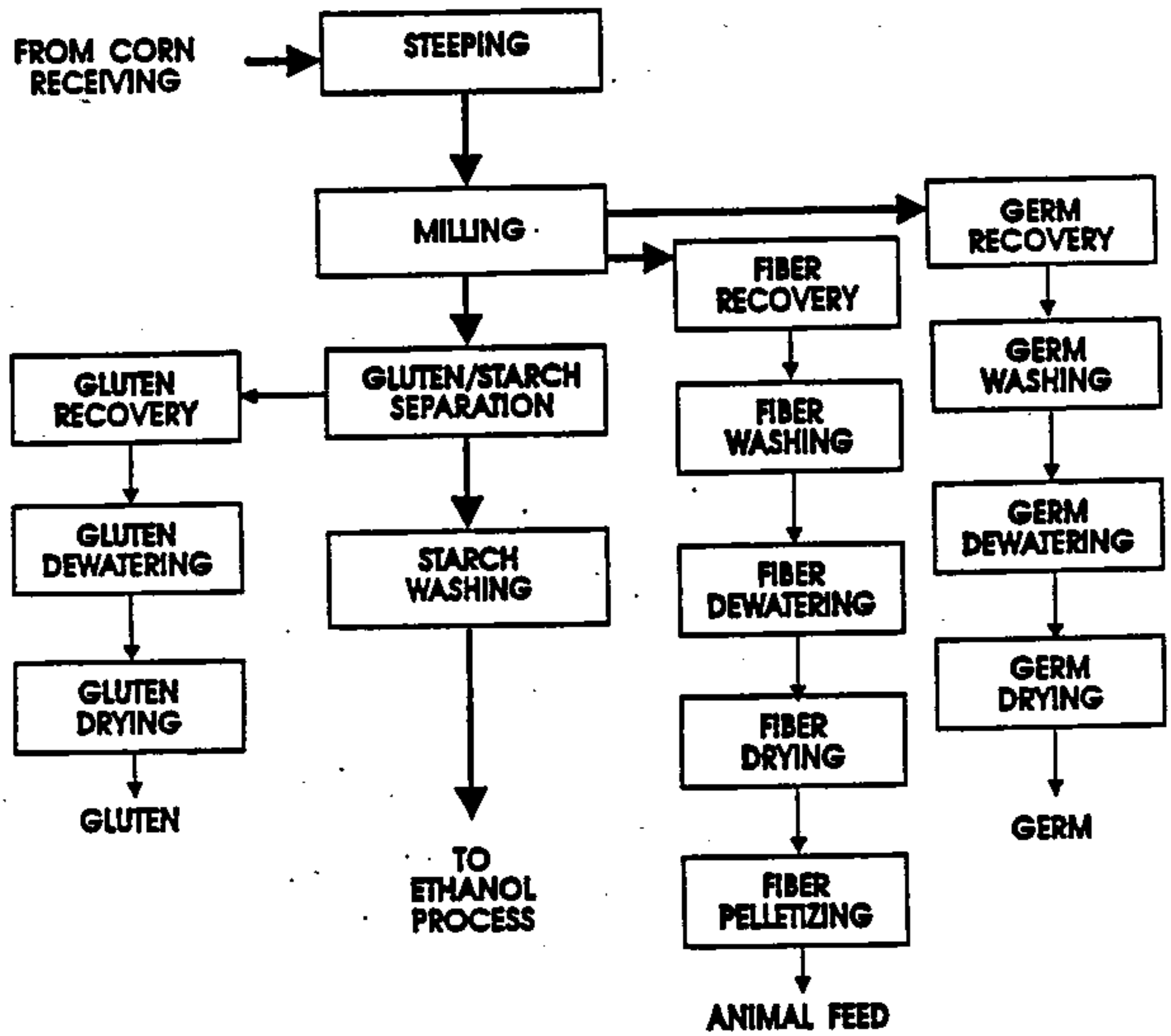
Wet milling processes generate many more by-products than dry milling, and these by-products normally are of higher value. Typical by-product yields from one bushel of corn are about 1.7 pounds of corn oil, 3 pounds of corn gluten meal (60% protein), 13 pounds of corn gluten feed (21% protein), and 17 pounds of CO_2.(21)

FIGURE 1.
DRY MILLING ETHANOL PROCESS



Source: New Energy of Indiana

FIGURE 2.
WET MILLING ETHANOL PROCESS



Source: New Energy of Indiana

Traditional Feedstock Costs

Table 8 shows the net corn costs (market price for corn minus the sales of by-products produced) associated with the wet milling process from 1981 to 1992 and the dry milling process from 1981 to 1989.

TABLE 8

NET CORN COSTS OF WET AND DRY MILLING PROCESSES

Year	Corn cost	Wet milling 1/				Dry milling 2/			
		Byproduct value as share of corn cost	Net corn cost			Byproduct value as share of corn cost	Net corn cost		
	Dollars/ bushel	Percent	Dollars/ bushel	Dollars/ gallon	Dollars/ ton	Percent	Dollars/ bushel	Dollars/ gallon	Dollars/ ton
1981	$3.16	47.01%	$1.67	$0.67	$59.64	41.0%	$1.86	$0.72	$66.43
1982	$2.40	58.36%	$1.03	$0.41	$36.79	51.5%	$1.20	$0.46	$42.86
1983	$3.12	50.40%	$1.55	$0.62	$55.36	44.6%	$1.73	$0.67	$61.79
1984	$3.11	45.63%	$1.69	$0.68	$60.36	34.0%	$2.05	$0.79	$73.21
1985	$2.52	46.96%	$1.34	$0.53	$47.86	33.8%	$1.67	$0.64	$59.64
1986	$1.95	62.04%	$0.74	$0.30	$26.43	54.7%	$0.88	$0.34	$31.43
1987	$1.59	83.69%	$0.26	$0.10	$9.29	69.6%	$0.48	$0.19	$17.14
1988	$2.36	67.56%	$0.77	$0.31	$27.50	58.2%	$0.99	$0.38	$35.36
1989	$2.62	59.52%	$1.00	$0.40	$35.71 4/	54.6%	$1.19	$0.46	$42.50
1990	$2.45	61.02%	$1.04	$0.41	$37.14				
1991	$2.40	56.47%	$0.94	$0.37	$33.57				
1992 3/	$2.38	59.18%	$0.97	$0.39	$34.64				

1/ CO_2 recovery not included; ethanol yield is 2.5 gallons, 1.55 lbs. corn oil, 13.5 lbs. CGF feed, 2.65 lbs. CGM meal per bushel.

2/ Dry-mill byproducts are evaluated at 125 percent of value of corn gluten feed, and yield is assumed to be 18 pounds/bushel; ethanol yield is 2.6 gallons/bushel.

3/ 1992 data only through October.

4/ 1989 data only through January.

Sources: USDA Economic Research Service, Resources and Technology Division
Wet Milling Data: Personal Communication with Jim Krubovcak 202/219-0403 January 21, 1993
Dry Milling Data: "Economics of Ethanol Production in the United States" March, 1989

As Table 8 illustrates, feedstock costs for ethanol production have varied over the past decade. Net corn cost for wet milling averaged $1.09/bushel, $0.44/gallon and $38.93/ton from 1981 to 1991.

B. EMERGING ETHANOL PRODUCTION TECHNOLOGY

This portion of the report will not duplicate the many good resources available for detailed information on the chemistry and technology of ethanol making.

The "List of Works Consulted" at the end of this report includes many such scientifically-based references and many others are readily available through the U.S. Department of Energy and the National Renewable Energy Lab.

Instead, this report will establish a lay understanding sufficient to grasp the importance of recent changes in the field which seem to offer promise for commercial production breakthroughs.

Cellulose-based Ethanol and Technology

Because subsidies can shift rapidly, research is perpetually conducted on other materials from which ethanol can be produced. Prominent among these is cellulose, found in such forms as trees, crops, stalks, cobs, digested and partially digested animal manure and in trash.

Cellulose-to-ethanol production is usually thought of as having three major phases:

1. Pretreatment
2. Conversion
3. Fermentation/Distillation

Pretreatment

Pretreatment is the phase in which organic material is physically broken down for the chemical trip from wood, waste paper, grass clippings or dozens of other familiar forms (and some unfamiliar industrial pulps, sludges and other by-products) to alcohol.

Traditional methods involve acid and/or heat as a means of separating the cellulose-containing material into components from which the sugar can be extracted.

Conversion

After pretreatment, the material is chemically broken down into three main substances: 1) cellulose, a fiber which can be converted to sugar; 2) hemicellulose, comprised of other types of sugar-based materials from plant cell walls and 3) the material which, in the raw form, bonds the cellulose together to form wood and woody substances (lignin).

The conversion process can be based on the addition of acid, enzymes or microbes to the basic material. Traditionally, this phase ends with the production of "sugar liquor," sugar molecules bonded with water.

Fermentation/distillation

Sugar liquor can then begin the age old process of fermentation in which sugar molecules are transformed into the molecules of liquid ethyl alcohol. Alcohols can be further concentrated through distillation.

Process Problems

The limits on the process of ethanol formation are the range of conditions under which catalysts (enzymes, microbes, yeast) can survive and continue the conversion process. Ironically, the products and by-products of the process--alcohol itself and heat are two important ones--kill these agents off, ending the conversion process.

Thus one part of the measure of technical efficiency of an ethanol making process is how much of the raw material can be converted in the process before the living agent is killed by the process.

There are hundreds, perhaps thousands, of variations on this process which can be learned in greater technical detail from the places and works cited above. But this description should give the lay reader a conceptual basis for understanding developments which may make the process market worthy.

Pitfalls From Lab to Production

Although papers have been written in the United States for decades extoling the possibilities of ethanol production from cellulose, not a single large-scale production plant contributes today to the more than one-billion-gallon annual capacity for producing ethanol.

Dr. Raphael Katzen, an engineer headquartered in Cincinnati, Ohio, who designed his first cellulose-based ethanol plant in 1945, cites the considerable range of dangers to yield that are inherent--and often unheeded by scholars and promoters--in large-scale production.

Dr. Katzen's firm, Raphael Katzen Associates International, Inc. in its work "Fuel Ethanol in USA: Review of Reasons for 75% Failure Rate of Plants Built" (1991), has documented that of 165 ethanol plants built in the United States since 1979, only 38 remain in production. (All references and quotations in this section are from the work cited above, presented at the International Symposium on Alcohol Fuels in Florence, Italy in 1991 and provided by Dr. Raphael Katzen.)

The researchers conclude:

> "While such factors as changing public policy, fraudulent investment schemes and government encouragement of financially non-competitive projects have contributed to project failures, the most significant causes have been improper technology selection and improper engineering design . . .
>
> ". . . None of the major mistakes were unavoidable. Adequate knowledge and experience existed prior to the decisions that resulted in these failures."

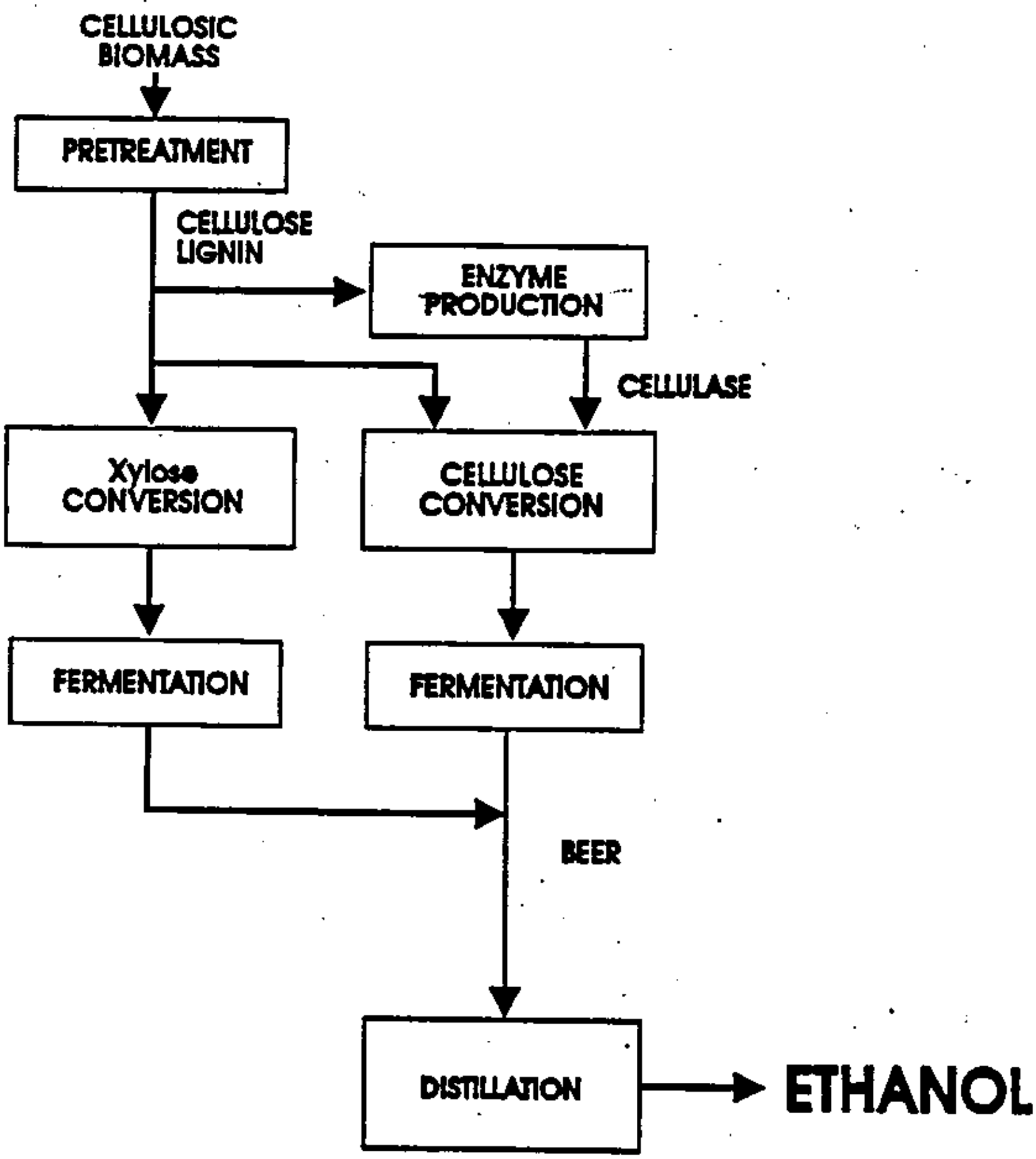
Technical failures cited by Katzen Associates include designs which failed at the cooking/sterilization step by assuming that "cooking" equipment used in paper making would serve the same purpose in grain-based ethanol production. In that case, the equipment was mechanically incapable of liquifying the whole grain feedstock and cooking temperatures were too low to sterilize the feedstock mix required for alcohol processing. According to the researchers, "The combined result was continuous, massive bacterial infection throughout. . ."

Other failures have included attempts to save costs by propagating yeast on-site, which Katzen Associates say resulted in "propagating infections by not providing adequate sterile design." Still other failures involved the use of yeasts purported to make alcohol at high temperatures. The Katzen report points out that the entire history of alcoholic beverage making, probably nearly as old as the human species itself, "is replete with attempts to use selected, thermophilic (heat-loving) yeast, to no avail."

After nearly 50 years of designing alcohol-making facilities of all sizes throughout the world, Dr. Katzen prescribes a simple solution to technical missteps. Despite his knowledge and experience--perhaps <u>because</u> of it--Dr. Katzen recommends that new lab processes be attempted first at the pilot level, then at the demonstration level and only then at the production level.

(Please see Figure 3 on page 39 for a process diagram of the cellulose-to-ethanol technology).

FIGURE 3.
CELLULOSE-TO-ETHANOL PROCESS



Source: New Energy of Indiana

Developments and Breakthroughs

For years, especially since the oil embargoes of the 1970's, researchers have tinkered with the basic three-step ethanol making process to improve its ultimate yield in alcohol.

If the process requires physical transfer of materials from bin to vat and vat to tank, for instance, the cost of the process is increased. If the process requires the separate addition of acids or enzymes with one set of survival characteristics at one stage, and addition of yeast or microbes at another with another range of operating conditions, these additions and the process controls they entail add cost.

In short, researchers have worked to unify the process and reduce the number of additives in order to reduce the cost of inputs and increase the value of output.

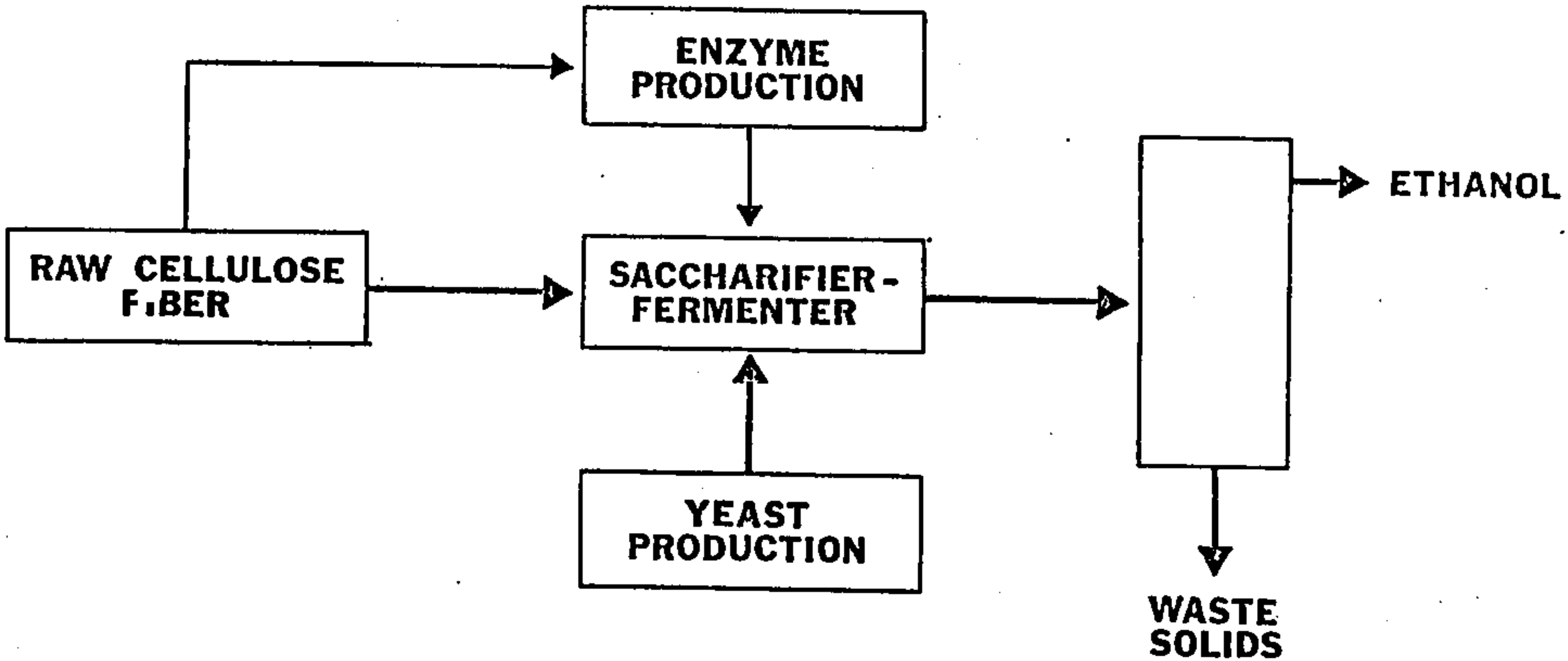
According to Dr. James D. Kerstetter, Bioenergy Manager of the Washington State Energy Office and author of "Mixed Waste Paper to Ethanol Fuel: A Technology, Market and Economics Assessment for Washington," these discoveries have added small incremental efficiencies to the process. They include such approaches as special pretreatment to speed up the exposure of cellulose to the breakdown process, various types of acid in varying concentrations to break the sugar bonds at less cost and experimentation with simultaneous processes in a single vat. They have typically resulted in claims of 2% to 3% of increased yield--important, but not breakthrough.

Recently, however, some biochemists claim potentially significant jumps in final alcohol yield through genetic engineering of microbes. To oversimplify, it is claimed that certain "superbugs" may be able to perform all of the jobs of conversion and fermentation in one operation and to do so under a greater range of chemical and temperature conditions than natural agents can survive.

In general, these breakthroughs, if they operate at production scale as their commercial proponents say they perform in the laboratory, could significantly alter the economics of production by elevating the alcohol yield of the entire process to levels which, some proponents claim, render the costs of marketing alcohol negligible.

(Please see Figure 4 on page 41 for a process diagram of a reduced-step method which is similar to the one being used for increasing yields through genetic engineering of microbes).

FIGURE 4. REDUCED STEP
CELLULOSE–TO–ETHANOL PROCESS



Source: Raphael Katzen Associates

V. COMPARISON OF FEEDSTOCKS

This section will evaluate various comparative measures between using corn and mixed waste paper as feedstocks for the production of ethanol.

YIELD COMPARISON

CORN

Traditional ethanol production facilities currently get 2.50 to 2.65 gallons of ethanol for each bushel of corn processed. One bushel of corn equals 56 pounds; therefore, yields per ton of corn vary between 89 to 95 gallons of ethanol.

MIXED WASTE PAPER

The Washington State Energy Office (WSEO) in its report "Mixed Waste Paper to Ethanol Fuel: A Technology, Market, and Economics Assessment for Washington" reviewed many of the technical aspects of the production of ethanol from mixed waste paper. WSEO evaluated various paper feedstocks and determined the following results:

TABLE 9

THEORETICAL & EXPECTED ETHANOL YIELDS FROM MIXED WASTE PAPER

Paper Type	Theoretical Yield (Gallons/Ton)	Expected Yield (Gallons/Ton)
Newspaper	89.0	56.07
Ledger Paper	122.0	76.86
Mixed Residential Paper	95.0	59.85
Mixed Commercial Paper	118.0	74.34

Note: Since no conversion process is 100% efficient, the actual yields will be less than theoretical. Typical cellulose to glucose conversions are 70 percent efficient and the conversion and recovery of ethanol from glucose is 90% efficient. Therefore, expected yields would be 63% of the theoretical yields.

Source: Washington State Energy Office Report, Page 5. 1991.

As Table 9 illustrates, ethanol yields from various waste paper feedstocks vary significantly.

The following table compares the yields that may be obtained from the two feedstocks:

TABLE 10

COMPARISON OF FEEDSTOCK YIELDS

CORN

Yields of 2.50 to 2.65 gallons per bushel of corn.

1 bushel of corn equals 56 pounds, and therefore equals 35.714 bushels per ton.

Yields:

High	94.64 gallons/ton
Low	89.29 gallons/ton

MIXED WASTE PAPER

Yields of 55 to 75 gallons per ton of waste paper.

1 ton equals 2000 pounds.

Yields: *

High	75.00 gallons/ton
Low	55.00 gallons/ton

* If the genetically engineered microbe process is able to increase yields by up to 30% as claimed, the yields stated above could be increased to a range of 70.00 to 100.00 gallons/ton, which would be very comparable with current yields from corn.

Source: Yields calculated by Economic Research Associates.

PRICE COMPARISON

CORN

According to the Nebraska Gasohol Committee, the Nebraska average price per bushel for corn was $2.38 in 1992. This equates into $85.00 per ton. Between 1983 and 1992, the Nebraska average was $2.40 per bushel, or $85.82 per ton.

In order to truly compare feedstock costs, we must remove all by-products produced during the corn to ethanol process to derive the net cost of corn (see Table 7). In 1992, net corn costs per bushel for wet milling were $0.97 per bushel or $34.64 per ton. Over the past decade, net corn costs have averaged $1.09 per bushel and $38.93 per ton, and $0.44 per gallon assuming a 2.5 gallon per bushel yield.

MIXED WASTE PAPER

Market prices for mixed waste paper vary significantly depending upon such variables as grade and quality of paper, transportation, and other market variables.

In order to try to compare ethanol feedstock costs "apples to apples", the following hypothetical example has been derived to show a range of waste paper costs per gallon of ethanol produced.

Table 11 compares ranges of "net paper costs" for various mixed waste paper products using yield estimates from the Washington State Energy Office.

TABLE 11

COMPARISON OF WASTE PAPER COSTS PER GALLON
OF ETHANOL PRODUCED

	DOLLARS/TON (Low)	DOLLARS/TON (High)	YIELD/TON (Gallons)	DOLLARS/GALLON (Low)	DOLLARS/GALLON (High)
NEWSPAPER	$15.00	$25.00	56.07	$0.27	$0.45
LEDGER PAPER	$40.00	$70.00	76.86	$0.52	$0.91
MIXED RES. PAPER	$10.00	$15.00	59.85	$0.17	$0.25
MIXED COMM. PAPER	$30.00	$50.00	74.34	$0.40	$0.67

Source: Paper prices per ton based on estimates obtained from east-central Nebraska recyclers.
Yield per ton information from : Washington State Energy Office. "Mixed Waste Paper to Ethanol Fuel: A Technology, Market, and Economics Assessment for Washington." Olympia, WA January, 1991.

Source: Calculations made by Economic Research Associates.

Therefore, if we compare feedstock costs per gallon for ethanol production:

CORN	$0.44/gallon
WASTE PAPER	$0.17 to $0.91/gallon

Newspaper would have the same price ratio as corn if newspaper was $25.00/ton or less; Ledger paper will substitute at just less than $40.00/ton; Mixed residential paper would substitute at just over $25.00/ton; and Mixed commercial paper would substitute at just over $30.00/ton.

VI. ETHANOL AND BUSINESS DEVELOPMENT

Although technical failure may lie behind much unrealized ethanol production, at least three other areas require consideration to understand both the state of the art and possible positive changes for Nebraska. They are:

--business factors,
--government policies, and
--environmental impact.

Business Factors in the History of Ethanol Development

While Raphael Katzen Associates International, Inc., attribute the high failure rate of ethanol production in the 1980's primarily to technical ineptness, they cite such financial problems as inappropriate capital investments, both those that were too high to be paid off by unstable operations and, at the other end of the spectrum, bargain-shopping which led to purchases of poor quality equipment. (All references are from "Fuel Ethanol in USA: Review of Reasons for 75% Failure Rate of Plants Built," Raphael Katzen Associates International, Inc., 1991).

In addition, Katzen Associates cite a lack of basic business planning. "Many investors failed to conduct feasibility studies and did not appreciate the time and expenses involved in building up stocks of ethanol and development markets," they conclude.

People who did know of these business factors, according to Katzen Associates, were established producers of industrial-grade and beverage alcohol. Katzen Associates suggest that established producers were often repulsed by the "low level of sophistication of the particular groups involved in the first plant proposals."

Therefore, they observe:

> "Many of the managers of the first plants had no previous experience with continuous industrial operations and lacked the ability to deal with labor and to delegate responsibilities. Thus, the management frequently worked long hours on technical operational problems and did not devote sufficient time to the equally important financial aspects."

Government Policy in the History of Ethanol Development

Investments based on government tax policies are extraordinarily risky. Yet much of ethanol development was built on the risky fortunes of tax abatements, production credits and consumption exemptions granted by state legislatures and the federal government.

In addition, Katzen Associates cite government funding of unproved technology and support for excessive capital costs through loan guarantees and other incentives.

Environmental Impact in the History of Ethanol Development

Katzen researchers note that early operators found it hard to meet environmental standards for liquid and atmospheric emissions. Those who have been successful in complying have encountered substantial capital costs as high as 10% of total plant investment.

Not observed by Katzen, but worth noting, is the constantly changing nature of environmental standards. The standard practices of 1979 were not the standard practices of 1989, nor certainly of 1993. Profits thrive in stability and the constantly changing state of the art of protecting the environment, without regard to capital costs, has acted against traditional practices of engineering and manufacturing.

Moreover, those who write and enforce legal standards are usually schooled in bureaucracy or the law, neither of which is known for its problem-solving approach to profitability.

What Are the Business Characteristics of Ethanol Development?

A Look at Key Business Ratios

While not definitive of the shape of a particular business or industry, statistically typical financial statements and key business ratios can shed light on the internal operations of "normal" businesses in defined lines of business.

Economic Research Associates has analyzed information from Industry Norms and Key Business Ratios (Desk-Top Edition 1991-92: Statistics in Over 800 Lines of Business, Dun & Bradstreet Information Services) to make the following generalizations on the nature of enterprises currently engaging in the production of ethanol.

Dun and Bradstreet draws its information on the business of ethanol production from an examination of financial data from businesses which may be publicly (in this case, publicly means owned by shareholders, not, as has been used elsewhere in this report, owned by government) or privately owned corporations, partnerships or proprietorships.

All businesses can be assigned a numeric code from the "Standard Industry Code" (SIC) of the U.S. Department of Commerce. The ethanol production industry is included in a category numbered 2869, for manufacturers of industrial organic chemicals. Data from 112 businesses in the United States are included in this category.

Dun and Bradstreet calculates average values from balance sheets and income statements from each of these businesses. These norms are then arrayed in a series of ratios that are considered standards for measuring the performance of individual companies.

Ratios are then sorted into three categories: the top quarter of performers, the half of all companies in the middle two quarters of performance and the bottom quarter of performers. Please see Table 12 on page 53 for a full accounting of these Dun & Bradstreet financial ratios.

Among the ratios which create some insight into the ethanol production business are:

1. The Current Liabilities to Inventory Ratio

This ratio is an indicator of inventory management. Insufficient inventory suggests lost sales; excess inventory suggests excessive costs. The lowest performing quarter of this industry shows signs of weakness due to excessive inventories. This finding confirms Economic Research Associates' emphasis on the importance of distribution in the ethanol industry.

2. The Fixed Assets to Net Worth Ratio

This ratio is an indicator of how well a company uses its net working capital. A high ratio indicates a company which may be supplementing its working capital with long-term debt, a poor business practice.

While standards vary widely by industry, ratios under 75% are a rule of thumb and the best and average performers in category 2869 are well under that measure at 29.7% and 67.4%. The worst performing quarter of the industry, however, shows long-term debt trouble with a ratio of 117.9%. Possible causes could include generous government lending, as cited by Katzen Associates above. If these companies do not pull out of this ratio, operations will cease when debt overwhelms revenues.

3. The Assets to Sales Ratio

This ratio measures how well the investments in generating sales are producing sales.

In this category, high performers show the hallmarks of a fast-growth industry with a relatively low ratio of 39.4%. Unless pockets are deep, this performance will lead to a business overcome by the pressures of its own short-term success. Because it is known that top performers in the ethanol production industry are supported by established corporations, the ratios are not alarming as they would be for unaffiliated businesses.

The middle range of performers show a moderate ratio of 60.6% which indicates a good balance between sales and sales investments.

The bottom quarter of performers, however, shows a distressing ratio of 113.3%, reflecting the weakness first discerned in the examination of inventory ratios. These would clearly be related ratios. Again, the marketing-related variable of distribution may lie beneath poor sales.

4. The Sales to Net Working Capital Ratio

This is also a measure of sales efficiency but with an added ability to discern the impact of fixed assets on poor sales. As might be expected, the high capital costs of entry into ethanol production appear to contribute to the relatively high costs of sales. Best performers show that the net working capital turns over 10.4 times a year in sales; middle performers show 6.3 turnovers; sluggish bottom performers turnover 3.3 times a year. The weight of fixed assets on overall production makes these performers a very poor use of investment capital. Without improvement, capital that can escape will leave. That which cannot escape will be lost.

5. Return on Net Worth (also known as Return on Equity)

Finally, the acid test. This is the one ratio that takes it all in, the measurement of management's ability to realize adequate return on the capital invested by the owners of the firm.

Top producers show an amazing 33.0% return on equity. Again, these numbers would be heavily skewed to the performance of the ethanol production segment of a massive, mature corporation which controls 80% of the production. This number demonstrates once again that in a capitalistic economy, capital dominates.

Middle performers show a return of 16.9% Does this mean that ethanol production is a good investment? Not in this case. Taken together with the lack of maturity of the industry, the domination by one giant corporation and the dismal results of poor performers, this return merely quantifies the average risk premium required to keep capital in place. Investors who can escape, would be likely to bail out of businesses with significantly lower returns. That which cannot be withdrawn will be dependent on the ability of management to respond to the other indicators and improve performance, will be condemned to a lifetime of underperformance or ultimately be lost.

Bottom performers show a return of 5.5%, a rate not at all attractive to investors. It is highly likely that all investors who can get out of these businesses are gone and only miraculous turn-arounds could save the remaining investment. These businesses are doubtless encouraged by the adoption of the *Clean Air Act* as just such a miracle. If, as is suspected, poor distribution is a significant factor in the illness of these enterprises, the broad geographic impact of the *Act* may bring some relief.

TABLE 12

FUEL ETHANOL INDUSTRY KEY BUSINESS RATIOS 1991-1992

SIC 2869 FINANCIAL RATIOS	UPPER QUARTILE	MIDDLE HALF	LOWER QUARTILE
SOLVENCY			
QUICK RATIO (TIMES)	2.1	1.2	0.8
CURRENT RATIO (TIMES)	3.5	2.1	1.4
CURR LIAB TO NW (%)	18.7%	44.4%	103.6%
CURR LIAB TO INV (%)	78.4%	142.9%	238.1%
TOTAL LIAB TO NW (%)	41.5%	92.5%	190.7%
FIXED ASSETS TO NW (%)	29.7%	67.4%	117.9%
EFFICIENCY			
COLLECTION PERIOD (DAYS)	33.2	52.9	67.5
SALES TO INV (TIMES)	19.0	9.1	6.1
ASSETS TO SALES (%)	39.4%	60.6%	113.3%
SALES TO NWC (TIMES)	10.4	6.3	3.3
ACCT PAY TO SALES (%)	3.3%	6.2%	8.7%
PROFITABILITY			
RETURN ON SALES (%)	11.3%	5.7%	2.5%
RETURN ON ASSETS (%)	15.1%	8.4%	2.5%
RETURN ON NW (%)	33.0%	16.9%	5.5%

* Note: Standard Industrial Classification Code (SIC) 2869 = Industrial Organic Chemicals, Not Elsewhere. Classified. SIC 2869 includes 112 U.S. businesses

Source: Dun and Bradstreet Industry Norms & Key Business Ratios, 1991-1992.

Another View

Analysis of the key business ratios is complemented by recent work of Dr. James D. Kerstetter of the Washington State Energy Office.

Dr. Kerstetter's findings on the impact of various business factors on Return on Investment (another term for Return on Equity) in ethanol development (he hypothesizes ethanol production from mixed waste paper, in this example) predict similar outcomes. His work tests the impact of a 10% change in select components of a modeled ethanol production enterprise. The single greatest effect on return, among those tested, is an increase in the price of ethanol. A 10% increase in the sales price of ethanol could be expected to increase return on investment by 23.6%.

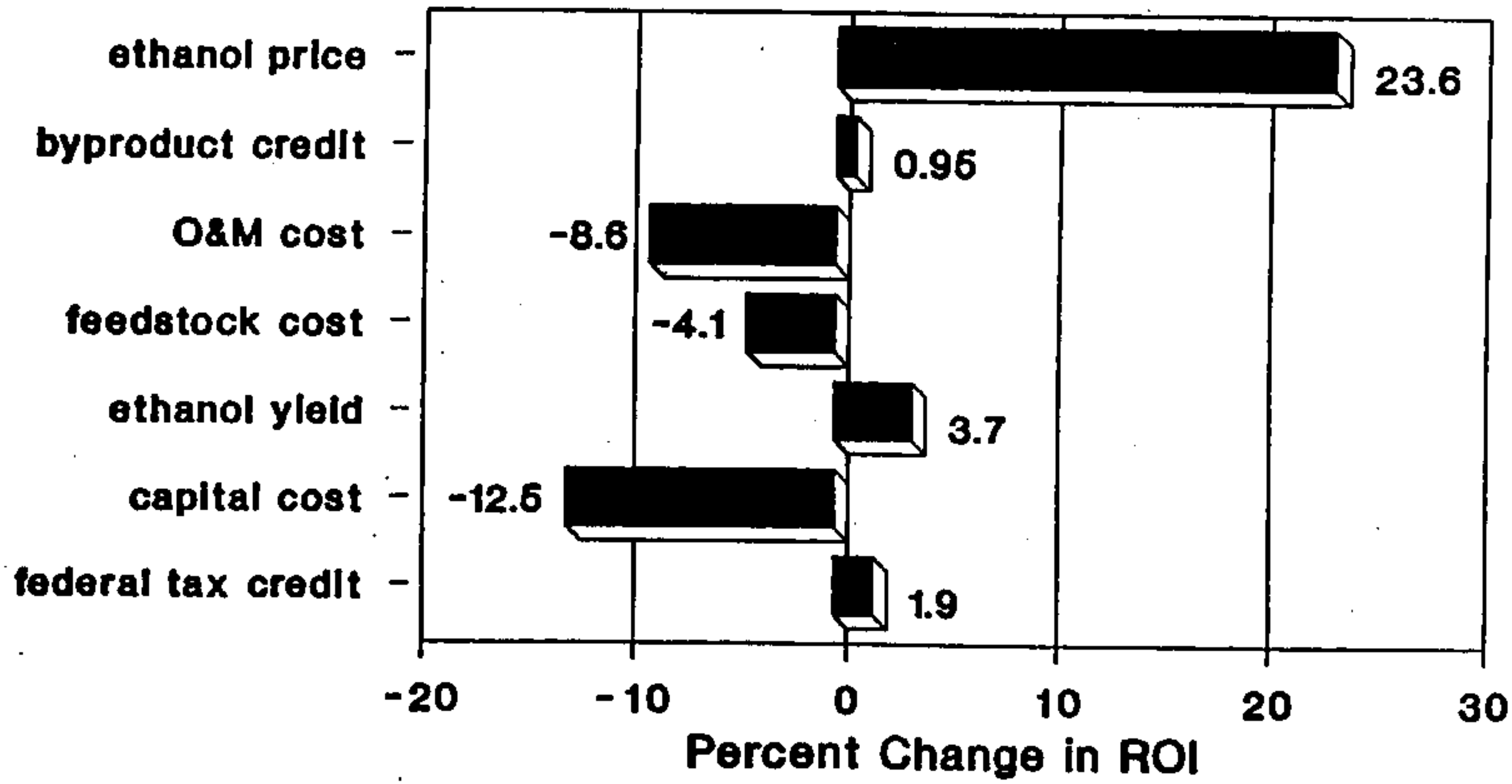
Interestingly, a 10% increase in the cost of capital would produce a 12.5% decrease in return on investment, the second greatest effect among those tested. This complements the findings of the key business ratios. Also supporting the ratio analysis is Kerstetter's prediction that a 10% increase in operating costs would have the next greatest impact on overall return. A 10% increase in operating costs would have an 8.6% negative impact on return.

Jumps of 10% in feedstock costs, however, under present conditions, would have only a 4.1% negative effect on return and a 10% increase in ethanol yield would have only a 3.7% positive impact on return. (Please see Graph 5 on page 53 for a full accounting of ROI sensitivity analysis results conducted by the Washington State Energy Office).

These two analyses suggest to Economic Research Associates that the focus on physical aspects of ethanol production may be overemphasized, especially by the national research facilities, while the health of enterprise is underemphasized.

Certainly, research on behalf of large corporations that already enjoy market dominance and who are already positioned to reduce operating and capital costs is misdirected public expenditure.

GRAPH 5.
Return on Investment Sensitivity to 10% Change



Source: Washington State Energy Office

What Industry Sector is Most Likely to Develop Ethanol from Mixed Waste Paper?

Setting aside small-scale, non-commercial development of ethanol from mixed waste paper or municipal solid waste, what are the industries most likely, based on their profile to enter into conventionally-sized ethanol production from cellulose sources?

In order to make any comments on the relative suitability of various industrial sectors to commercial ethanol development from cellulose, it is necessary to "freeze" some business variables. This would never be the case in a real life application. In actual experience, factors are interdependent and the business environment is ever-changing, often without any cogent explanation. As noted elsewhere in this work, such independent events as a stock market correction which affects the interest rate or such closely related events as an energy tax will throw previous calculations into chaos.

That said, an examination of three industrial areas which have been suggested as possible developers of ethanol from mixed waste paper will be discussed:

--Petroleum
--Waste management
--Agri-business

Petroleum

Except through intercorporate affiliations, the petroleum industry has declined to take the exploratory lead in ethanol development from corn. Should this be taken as the pattern that will pertain to cellulose development?

These new factors should be considered in considering the involvement of the petroleum industry:

--Passage of The *Clean Air Act*, mandating cleaner emissions across a broader geography. Few industries have as broad a distribution system as petroleum. This may become a comparative asset under the new standards which would give petroleum the edge it needs to enter development.

--Interviews for this project have revealed that Amoco is reputed to be interested in working with a governmental research facility on a $24 million pilot/demonstration cellulose-based plant in the upper Midwest, presumably near existing corn-based distribution channels in Illinois. The project would be an initiative of Amoco's non-petroleum products research division.

--Meanwhile, the industry has its own problems reacting to restrictions on development of new sources, a "no sacred cows" deficit reduction mentality which may challenge exploration and operating subsidies that were given special treatment, especially in the previous four years.

In general, petroleum has been more inclined to expand vertically through its field than horizontally into other lines. It is not likely to be the first or biggest entrant into development.

Waste Management

--Business is booming. For large operators, profits can be high and growing. Regulation weighs in on the side of strength for this industry. Continued strength suggests future diversification and industrial pockets may be deep.

--Small companies, such as Quadrex of Gainesville, Florida, are exploring the continuum, long discussed in theory, of the similarity of disposal and development. Increasingly, the energy production and development requires comfort and familiarity with the technology of disposal.

--Many business aspects of waste management are more like a utility or service industry than a production industry. Capital structures, operations and profits are all quite different in these two widely different enterprises.

More development of the disposal/development continuum will be required to make waste management a front runner in ethanol development.

Agri-business

--Conservative business analysis weighs in on the side of the industry that has already invested heavily in development of ethanol from corn.

--Ethanol development now is dominated by agribusiness which made reasonable decisions in locating production facilities along least-cost transportation routes. Unless there is a radical change in the composition of production and marketing costs (such as a bioengineering breakthrough at the operations scale) it is likely that the existing configuration will remain in place.

The Small-Scale Option

Because this is a somewhat pessimistic prediction for Nebraska, Economic Research Associates suggests examination of another option, small-scale near- or on-site developments which yield immediate benefits to communities now struggling with newly-imposed burdens of waste management.

This option makes special sense in a state where municipalities may also be involved in small-scale power management and generation.

Characteristics of Individual Businesses Most Likely to Succeed in Commercial Development of Ethanol from Cellulose

Economic Research Associates suggests these characteristics of high performers in ethanol development in the future:

Structural Flexibility

Increasingly, successful enterprises are those which seek and use information about themselves, their business environment and others in their field. They plan for change and expect that external conditions will change rapidly and without warning.

They are likely built of small units which are interdependent in business areas of high control and stability and independent in business areas of uncertainty where the business has little control.

Successful companies will expect change in environmental regulations and integrate these costs, rather than spending equivalent or larger sums resisting them.

Planned Stability

Successful businesses will protect themselves from direct contact with unstable supply and sales markets by locking in mid-term supply and sales prices by contract.

Distribution Planning

In this field especially, distribution channels are significant to profit.

It is likely that large-scale operations will continue to concentrate themselves along established channels where massive transportation and storage investments have already been made and amortized.

Among developing factors which may mitigate against this tendency are:

- -- bioengineering breakthroughs, <u>if they deliver the magnitude</u> of production cost savings proponents suggest
- -- government policies, including the implementation of The *Clean Air Act* and proposed energy tax policies

Because of the focus of research and development on large-scale commercial operations to the virtual exclusion of small-scale and publicly owned facilities, little has been written about the potential for such operations in recent times. There is some historic evidence, however, that, depending on the total price of fossil fuels, small-scale plants located near mixed waste paper or municipal solid waste sources may return positive benefit/cost ratios.

Such installations would be immune to the distribution problems of large-scale commercial production and might even be "closed-loop systems" in which the ethanol energy produced is used by the system owner in site operations. For limited periods of time under unique sets of costs, such applications are said to have been effective for private enterprises. Although scant documentation of these installations has been discovered in the course of this broad inquiry, promising leads (a Gulf Oil pilot plant in Pittsburg, Kansas, in the 1970's, for instance, and a paper sludge plant within the James River paper company) were turned up which suggest additional investigation.

It is possible that recent developments in integrated resource planning, as mandated in many states by public utility commissions, may be leading to the development of energy/resource models which quantify, at relatively small scales, the benefits of operations with both disposal and production benefits. It was not possible to develop that line of inquiry within the confines of this project but, Economic Research Associates suggests that this could be an extremely beneficial project for further inquiry.

Assumptions embedded in commercially-oriented models such as those used at TVA and NREL make them inappropriate for this purpose. Moreover, these models, are likely to have been developed under the standards of computing which are now several generations old and which are not considered transferable or user friendly.

VII. OTHER ISSUES

Two other issues have come to light during this project that should be addressed: (1) The issue of sustainability; and (2) The question of what feedstocks will qualify for Nebraska ethanol related tax incentives.

SUSTAINABILITY

Some may question the wisdom of making ethanol from waste paper. Some may claim that in a truly sustainable society, paper should be recycled indefinitely.

The fact is that paper can not be recycled indefinitely. Each time paper is recycled, the fibers which bond the paper together become shorter, and after a certain amount of "recyclings" (four to seven times on average), the fibers become to short to bond and the paper must be disposed of anyway.

Then the question becomes "What is the best option for the disposal of the short-fibered waste paper?"

LEGAL ANALYSIS

Nebraska law is unclear about whether ethanol production from non-agriculturally derived products would qualify for state ethanol tax incentives. Statutory analysis of this type is beyond the scope of this project but, should be investigated by the Nebraska Energy Office before engaging in ethanol production ventures using waste-derived products as feedstocks.

VIII. ENDNOTES

(1) National Advisory Panel on the Cost-Effectiveness of Fuel Ethanol Production. "Fuel Ethanol Cost-Effectiveness Study Final Report." U.S. Department of Agriculture, Office of Energy, Washington D.C. November, 1987.

(2) Information Resources, Inc. "The Impact of the Clean Air Act on Motor Fuels: An Analysis of Reformulated Fuels and Oxegenates - 1990 to 2000." Washington D.C. December, 1990.

(3) Information obtained from personal communication with Mr. Jim Hrubovcak, U.S.D.A. Economic Research Service Resources and Technology Division. Washington D.C. 202/219-0403. January, 1993.

(4) Jim Hrubovcak personal communication, op. cit.

(5) Information obtained from personal communication with Mr. Steve Sorum, Nebraska Gasohol Committee. Lincoln, NE 402/471-2941. November, 1992.

(6) Commerce Clearing House Staff, _Clean Air Act: Law and Explanation_ (Chicago: Commerce Clearing House, 1990) p.16.

(7) Michael Walsh, "Motor Vehicles and Fuels: The Problem," _The EPA Journal_ 14 (January/February 1991) pp. 12-14.

(8) Information obtained from personal communication with Mr. Doug Durante, Executive Director, Clean Fuels Development Coalition. Bethesda, MD 301/913-9636. December, 1992.

(9) Office of Solid Waste "Memorandum regarding future costs Municipal Solid Waste Management" United States Environmental Protection Agency. Washington, D.C. September, 1992.

(10) SCS Engineers "State of Nebraska Solid Waste Management Plan." Kansas City, MO. November, 1991.

(11) This percentage growth rate of 0.34% for municipal solid waste generation is typical of growth rates used by the U.S. Environmental Protection Agency.

(12) SCS Engineers "Nebraska Solid Waste Management Plan." op. cit.

(13) Users of this study should contact Mr. Bruce Ehrich at 402/444-6866. Mr. Ehrich is the Environmental Planner for the Metropolitan Area Planning Agency located in Omaha, NE.

(14) Information obtained from personal communication with Mr. Al Collison, owner of Parco Insulation, Inc. Norfolk, NE 402/379-2040. January, 1993.

(15) Information obtained from personal communication with Mr. Ed Cook, manager of the Omaha Recycling Facility, which is operated by Waste Management, Inc. Omaha, NE 402/341-0404 December, 1992.

(16) Information obtained from personal communication with Mr. Gene Hanlon, Recycling Coordinator for the City of Lincoln, NE 402/441-7043. March, 1993.

(17) Information obtained from personal communication with Mr. Steve Danahay, Recycling Coordinator for the State of Nebraska, Lincoln, NE 402/471-2431. December, 1992.

(18) Al Collison personal communication, op. cit.

(19) U.S.D.A. "Cost-Effectiveness Study." op. cit. and U.S. Department of Agriculture. "Economics of Ethanol Production in the United States." U.S.D.A. Economic Research Service. Washington D.C. March, 1989.

(20) U.S.D.A. "Cost-Effectiveness Study." op. cit.

(21) U.S.D.A. "Cost-Effectiveness Study." op. cit.

IX. LIST OF WORKS CONSULTED

Beall, David S. K. Ohta and L.O. Ingram. "Parametric Studies of Ethanol Production from Xylose and Other Sugars by Recombinant Escherichia coli," Biotechnology and Bioengineering, Vol. 38, 1991.

Becker, D.K., George H. Emert and Raphael Katzen. "The Development Rationale for Ethanol from Lignocellulosics." Cincinnati, OH: Raphael Katzen Associates International, Inc.

Bevernitz, K.J., R.E. Fredrickson, K.F. Kaupisch and G.H. Emert. "Economics of a Combined Resource Recovery Cellulose Alcohol Plant." Fayetteville, AR: Biomass Research Center, University of Arkansas, September, 1982.

Bioenergy International, L.C. "Fact Sheet" Gainesville, FL: Quadrex.

Center for Infrastructure Research. "Developing Markets for Recyclables in Eastern Nebraska and Western Iowa - Summary of Research." University of Nebraska-Lincoln, Lincoln, NE April, 1990.

Clean Fuels Development Coalition. "Clean Fuels: Paving the Way for America's Future - A Compilation of Current Information on Clean Burning Alternative Transportation Fuels." Washington, DC Spring, 1991.

Dun & Bradstreet Information Services. Industry Norms & Key Business Ratios, Desk-Top Edition, 1991-92. Dun & Bradstreet Information Services.

Easley, Charles E., Kurt Bevernitz, Dana Becker, Edwin A. Stewart and Edward F. Hetzel. "Cellulosic Waste Conversion to Ethanol Using Fed-Batch Simultaneous Saccharification and Fermentation." Paper presented at the Institute of Gas Technology, 13th Annual Conference, 1989. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH).

Emert, George H. and Raphael Katzen. "Chemicals from Biomass Improved Enzyme Technology." Paper presented at Biomass As a Non-Fossil Fuel Source Symposium, Honolulu, HI, 1979. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH).

Emert, G.H. and Raphael Katzen. "Gasohol/Biomass Developments: Economic Update of the Gulf Cellulose Alcohol Process." Chemical Engineering Progress, September, 1980.

"How Some Companies Bomb in Booming Waste Market." Wall Street Journal, November 21, 1989.

Ingram, Lonnie O., Tyrrell Conway and Flavio Alterthum. "United States Patent Number 5,000,000," March 19, 1991.

Katzen, Raphael. "The Advancing Technology for Oxygenated Fuels in Gasoline: Based on Ethanol from Biomass." Cincinnati, OH: Raphael Katzen Associates International.

Katzen, Raphael. "Bio-Conversion of Cellulosic Wastes." Paper presented at American Institute of Chemical Engineers Annual Meeting, Forest Products Division, Biotechnology Session/183, Los Angeles, November, 1991.

Katzen, Raphael. "Ethanol from Ligno-Cellulose Utilization of Agricultural and Forest Residues." Paper presented at The Agro-Industrial Revolution Conference, Washington, D.C., June, 1990. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH).

Kerstetter, James D. "Ethanol Fuel from Mixed Waste Paper," copies of audio-visual materials. Olympia, WA: Washington State Energy Office, 1991.

Kerstetter, James D. and John Kim Lyons. "Mixed Waste Paper to Ethanol Fuel: A Technology, Market and Economic Assessment for Washington." Olympia, WA: Washington State Energy Office, 1991.

Lincoln, Nebraska Recycling Office. "1990 Solid Waste Characterization Study for the City of Lincoln and Lancaster County." Lincoln, Nebraska. September, 1991.

Madson, Philip W. and John E. Murtaugh. "Fuel Ethanol in USA: Review of Reasons for 75% Failure Rate of Plants Built." Paper presented at International Symposium on Alcohol Fuels, Firenze, 1991. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH).

Metropolitan Area Planning Agency (MAPA). "MAPA Regional Solid Waste Management Report." Omaha, Nebraska. February, 1985.

Ohta, Kazuyoshi and D.S. Beall, J.P. Mejia, K.T. Shanmugam and L.O. Ingram. "Metabolic Engineering of Klebsiella oxytoca M5A1 for Ethanol Production from Xylose and Glucose," Applied and Environmental Microbiology, October, 1991.

"Overflow Crowd Attends Ordinance Hearing; Board Approves Changes." Floyd (Virginia) Press, December 19, 1991.

National Renewable Energy Laboratory. "A Tradition of Technology Transfer." Golden, CO, 1992.

National Renewable Energy Laboratory. "Biotechnology Research at the National Renewable Energy Laboratory." Golden, CO: 1992.

National Renewable Energy Laboratory. "New Directions in Energy Independence." Golden, CO: 1992.

National Renewable Energy Laboratory. "Turning America's Industrial Wastes Into Profit$ with NREL." Golden, CO: 1992.

Peat Marwick Main & Co. Building the High Technology Business. 1988.

Pinson, Linda and Jerry Jinnett. Anatomy of a Business Plan, third printing, revised. Fullerton, CA: Out of Your Mind. . . and Into the Marketplace, 1989.

Quadrex. Various materials distributed at a briefing in Nebraska. Gainesville, FL: Quadrex.

Quadrex. "1991 Annual Report." Gainesville, FL: Quadrex, 1992.

Quadrex. "Commingled Waste Disposal Program," Coraopolis, PA: Quadrex Energy Services Corporation.

Quadrex. "Nuclear Decontamination and Recycle Center Services for Metals," Coraopolis, PA: Quadrex Energy Services Corporation.

Revised Statutes of Nebraska, 1943. Reissue of 1992. Chapter 66-1301 to 1326 and Chapter 81-1501 to 1574.

Russo, Lawrence J. "Commercializing Technology: New Energy Company of Indiana - A Case Study." Presented at the 1992 Biobased Products Exposition, St. Louis, MO October, 1992. (Copy supplied by Linda Bluestein, DOE National Alternative Fuels Hotline, Washington, DC)

Sask Report. Untitled article on Pound-Maker Adventures Ltd. integrated feedlot/fuel ethanol facility project in Canada. January/February, 1992. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH)

Securities and Exchange Commission. "Form 10-K: Annual Report Pursuant to Section 13 OR 15(d) of the Securities Exchange Act of 1934 for Quadrex Corporation for the Fiscal Year Ended December 31, 1991." Washington, DC, 1992.

Siegel, Eric S., Loren A. Schultz, Brian R. Ford and David C. Carney. The Ernst & Young Business Plan Guide. New York: John Wiley & Sons, Inc., 1987.

"'Superbug' Can Convert Plants Into Ethanol," Cincinnati Enquirer, January 3, 1993.

"TVA 'Most Likely' Will Operate Bellefonte." Huntsville (Alabama) Times, November 29, 1989.

U.S. Congress, Office of Technology Assessment. Energy from Biological Processes. Washington, D.C.: U.S. Government Printing Office, 1980.

U.S. Department of Energy. "Announcing: The Alternative Fuels Data Center." Golden, CO: 1992.

"A Very Public Man in Private Industry." Gainesville (Florida) Sun.

"Waste-Site Access Concerns Firm," editorial. Grand Island Independent, November 15, 1990.

"Waste-to-Fuel Technology Is Firing Up Quadrex Corp." Wall Street Journal, November 3, 1992.

Wyman, C.E. "The DOE/NREL Ethanol from Biomass Program." Golden, CO: National Renewable Energy Laboratory, 1992.