SUBSTITUTING AGRICULTURAL MATERIALS

FOR

PETROLEUM BASED INDUSTRIAL PRODUCTS

Principal Investigators:

David Morris, Self-Reliance, Inc.
2425 18th St. NW
Washington, DC 20009

Tom Abeles, i/e associates
3704 11th Ave. S.
Minneapolis, MN 55407

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INDUSTRIAL PRODUCTS FROM PLANT MATTER

SUMMARY

Significant markets exist for industrial products from plant matter. Several of these markets require little or no further research and development. Much larger markets can be achieved through concerted marketing and commercialization. Spurred by the surplus of agricultural crops, the federal government and several national trade associations have targeted new market development for existing crops and new crop development for non-feed or food purposes. This report focusses on those new markets and alternative crops that impact directly on the consumption of fossil fuels.

Currently, the best return to biomass is available by displacing petroleum from high value specialty chemical markets. These markets tend to be small, except for a half a dozen high demand chemicals. About 90 percent of all petroleum products are presently used as fuel. Thus if one is to have a substantial impact on national agricultural prices by using large quantities of biomass, the fuel market must be penetrated.

The rapid growth of ethanol is one example of a high volume market. It should be noted, though, that consumer fears of gasohol and depressed oil prices mean there is significant competition for ethanol in the octane enhancer markets. Since corn, even at depressed prices, represents more than 40 percent of the total cost of producing ethanol, swings in pricing when volume is high and margins small may not provide the stability and viability needed to establish a biomass fuels industry.

Active research continues to develop processes for conversion of lignocellulose to ethanol. While potential margins in this area appear to be greater than in the starch-based ethanol conversion they are realized only if markets can be found for co-products such as lignin or furfural. Yet given the disparity between fuel requirements and chemical markets, these byproducts would saturate existing chemical markets even at relatively modest levels of ethanol production.

Stricter environmental regulations may provide attractive alternatives for stimulating the biomass industry by targeting those products that have a high avoided cost due to environmental concerns. These costs can sometimes be internalized in the producer's economics(e.g. consumption of whey waste) but often have social costs involved(e.g. salt for de-icing) that allows a governmental entity to make the cost-benefit analysis and provide incentive programs.

Thus biomass chemicals, whether from new or existing crops, face two major obstacles.

1. High production means competing for large volume, low margin markets which will tend to be volatile, similar to the traditional feed/food commodities.

2. High margin products or commodities tend to have low volume markets.

Despite these potential problems biomass can effectively be used to create commodities that will economically displace petroleum products in the fuel and chemical

markets. The production of these commodities can reduce dependency on non-renewable resources. The diversification into these areas opens up new opportunities for the agroforestry sector. Yet it cannot in and of itself be considered a solution to the larger problem of overproduction.

This report is designed to identify opportunities for agroforestry products in an arena normally dominated by petroleum based commodities. It is designed to identify opportunities for the state of Nebraska to reduce its dependency on fossil fuels while creating new markets for its agricultural crops.

OVERVIEW

Nebraska devotes approximately 18 million acres to its principal crops. The state produces approximately 35 million tons of marketable plant matter; perhaps half as much plant matter remains in the field.

TABLE 1

Nebraska Agricultural Production-1984(Major Crops)

Grain	Planted acres	Production(bu)	Yield bu./acr.
Corn	7.5 million	800 million	120
Wheat	2.3 Million	82.8 million	36
Sorghum	1.9 million	122 million	64
Soybeans	2.3 million	84.9 million	36
Hay	3.3 million	6.75 million(tons)	2.2 t./ac.

Overproduction in the agricultural sector has led producers to seek new uses for existing crops and to identify new crops that allow for diversification. This study builds on this interest and momentum by focussing on opportunities specifically relating to the displacement of petrochemical products.

TABLE 2

Nebraska Energy Consumption/1983

Fuel	Quantity	Trillion Btus
Petroleum	38.2 million barrels(7.6 million tons)	202
Coal	5.9 million short tons	104
Natural Gas	129 billion cubic feet	133

TABLE 3

Pathways From Plant Matter and Petroleum to End Products

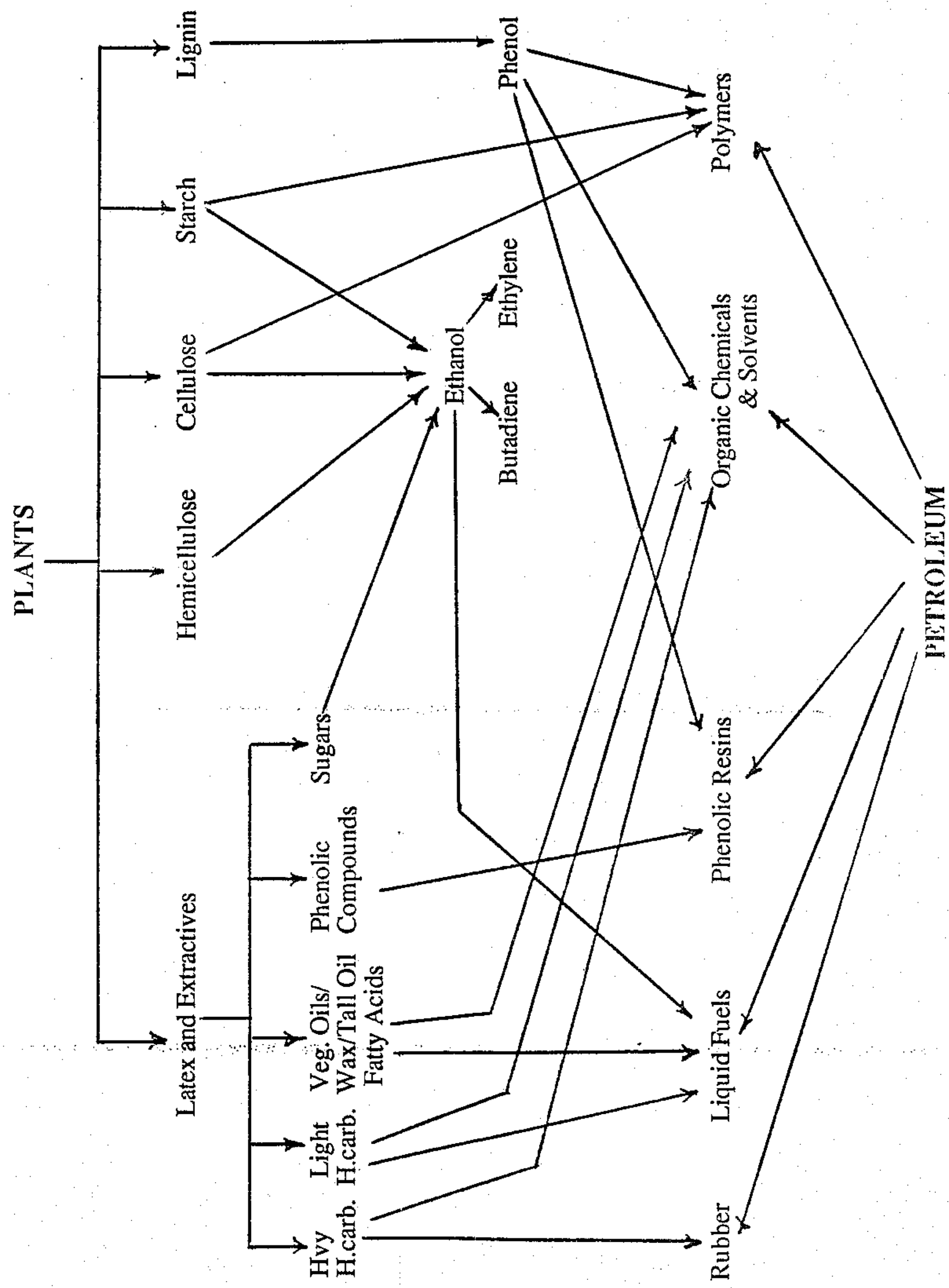

Table 3 provides an overview of the various paths by which plant matter can be made into fuels and chemicals. Table 4 lists the present demand for chemicals and fuels.

TABLE 4

Demand for Selected Chemicals and Fuels-1982

Fuel/Chemical	Units(106)	Demand
Ethylene Oxide	pounds	5,500
Ethyl Acetate	pounds	250
Chemical Grade Ethanol	gallons	200
Fuel Ethanol	gallons	400
Gasoline	gallons	75,000
Ethyl benzene	pounds	8,000
Vinyl Chloride	pounds	7,000
Low density polyethylene	pounds	5,000
High density polyethylene	pounds	5,000
Formaldehyde	pounds	2,500
Celanese fuel methanol	gallons	900
Chemical grade methanol	gallons	250
Acetic acid	pounds	1,500
Acetaldehyde	pounds	550
Ethylene dichloride	pounds	1,800
Butanol	pounds	800
Adipic Acid	pounds	1,200
Butadiene	pounds	1,800
Styrene	pounds	5,900
Maleic Anhydride	pounds	300
Furfural	pounds	140

Corn represents approximately 60% of the agricultural material produced in Nebraska. Since 1978 two significant new market developments have occurred to assist the corn industry: the development of ethanol and corn sweeteners. Nationally, in 1979 ethanol consumed about 10 million bushels of corn. In 1984 this rose to 172 million bushels and to 240 million in 1985. Demand for corn sweeteners rose from 200 million in 1977 to 500 million bushels in 1985.

TABLE 5

Corn Uses: 1970 and 1975

Type	1975	1985
Feed and other(seed, seed corn, residual loss)	62%	48%
Export	22%	25%
Industrial Processing	9%	13%
Carryover	7%	14%

However, as can be seen from Table 5, the surplus increased even faster than new industrial uses of corn. With predictions of a surplus of almost 3 billion bushels for 1986 the National Corn Growers Association(NCGA) in late 1985 established the Corn Utilization Conference and in January 1986 the NCGA and Funk Seeds International announced the creation of the Corn Utilization Project. A report of the first meeting of the Blue Ribbon task force, which includes representatives from the largest corn processing firms should be available by June 1986.

Currently NCGA predicts a demand for ethanol equivalent to 1 billion bushels of corn by 1990 due to lower lead requirements in gasoline. However, corn faces stiff competition from both petroleum based octane enhancers and from other types of biomass.

The price of ethanol tracks the price of oil but the relationship is not exact. With crude oil priced at about $15 per barrel, Octane Week, May 5, 1986 reports the following prices of the major competing octane enhancers.

TABLE 6

Comparative Price of Octance Enhancers/May 1986

Product	Blending Value	Price/$
Toluene	76	.65
MTBE	69	.63
Ethanol	64	.20*

*This allows for 6 cent federal subsidy plus 3 cent state subsidy per gallon of gasoline.

However, there are additional costs for ethanol. These include increased handling costs at the refinery and increased paperwork for several parties related to tax credits. Moreover, the opposition by some customers to the use of ethanol and the effective advertising campaigns by those retail stations that do not use this additive, raises the effective cost of ethanol. In May 1986 Mobil Oil Corp announced a decision to stop using ethanol in the Minneapolis/St. Paul area and in Chicago, and Total Petroleum Inc. stopped selling gasohol in the Minnesota. Both companies cited customer preferences as the basis for their decision. In 1984 only 1.5 percent of the gasoline sold in Minnesota contained ethanol. By the end of 1985 ethanol blended gasoline accounted for 41 percent of sales.(This was also the period in which the state sales tax exemption went from 2 to 4 cents per gallon) So far in 1986 the figure has slipped to 29.5 percent and may drop below 20 percent by the end of the year. There also appears to be a surplus of ethanol on the market.

The result is that ethanol producers are forced to price ethanol at .95 to $1.10 per gallon, depending on whether they are selling into a state with tax credits or not. This leaves no margin for profit. Indeed, it might be driving the smaller producers that do not see ethanol primarily as a byproduct of other production processes out of the market.

One result has been the recent decision by the Secretary of Agriculture to release from Commodity Credit Corporation inventories corn to alcohol producers. In regulations due to be released by mid May the Department of Agriculture will propose to give one bushel of corn for every 2.5 bushels used by an ethanol producer. This will in effect save 15 cents per gallon of ethanol. Conceivably it would consume 30-50 million bushels from the CCC surplus. The program will run until the fall when it is expected that higher oil prices and/or lower grain prices will make it unnecessary. The program will benefit the farmer only indirectly. However, as a precedent it can be very useful for states like Nebraska that are actively seeking to develop new industrial markets for corn flour and corn starch and corn stover. The Department of Agriculture may be asked to provide free surplus corn in matching quantities for experimental and small commercial runs of new materials to open up new markets.

TABLE 7

Effect of Corn Cost on Ethanol Cost*

Cost/bushel/$	Corn	Conversion	Total Base Costs**
2.00	74.0	25.4	99.4
2.25	83.3	25.4	108.7
2.50	92.6	25.4	118.0
3.00	111.0	25.4	136.4
3.50	129.5	25.4	154.9

*2.7 gal of 200 proof alcohol/bushel
**Excluding profits nor marketing costs and transportation. Costs will not rise quite this rapidly since distillers grain prices will also rise with corn prices.

There are continuing efforts to find alternatives to corn as an ethanol feedstock. A promising competitor is sweet sorghum(discussed below under New Crops). Another is lignocellulosic material. The economics of conversion from cellulose depends in large degree on the development of markets for the hemicellulose and the lignin. Current research in furfural and lignin indicate that these can become valuable byproducts, reducing the cost of ethanol from wood and agricultural residues below that of corn(See below for a discussion of furfural and lignin under New Products).

If breakthroughs occur in the lignocellulosic market Nebraska still has significant resources. Nebraska has opportunities for coproduction with other products and for intentional production. Green wood chips cost about $10-15 per ton delivered. According to one Minnesota study, the cost of gathering agricultural residue from fields at the roadside would be $5-10 per ton, competitive with wood chips. However, the opportunity is not a panacea. States that are rich in biomass will start to produce their own ethanol fuels and produce their own byproducts which will go into the same feed/food and chemical markets.

TABLE 8

Composition of Various Types of Biomass(% Dry Weight)

Material	Cellulose	Hemicelluloses	Pentosan	Lignin	Extractives
Temperate					
Hardwoods	43-45	23-35	12-24	16-24	2-8
Softwoods	41-43	24-33	8-14	24-33	1-7
Grasses	25-40	25-50	25-29	10-30	--
Corn Cobs	41	36	--	6	14
Corn Stalks	29	28	--	3	--
Wheat Straw	40	29	--	14	--

The price drop in oil has lowered almost all chemical prices as well. Table 9, based on information from the Chemical Marketing Reporter, shows a comparison of chemical prices for January 1981 and January 1986.

TABLE 9

Comparative Prices of Chemicals

Chemical	Jan./81	Jan./86
Crude Oil(bbl)	$36	$20
Acetic Acid	.24	.25
Benzene	$1.80/gal	.82-.85/gal
Butadiene	.34	.26
Ethyl Alcohol*	$1.80/gal.	$1.30/gal.
Ethylene Oxide	.41	.18-.20
Formaldehyde	.69-.74	.88-$1.00
Furfural*	.63	.75
HDPE	.44-.49	.43-.49
LDPE	.41-.48	.36-.45
Maleic Anhydride	.42-.50	.55
Styrene	.37	.22
Toluene	.80/gal.	.58-.60/gal.
Vinyl Chloride	.17	.28

*This is not a petroleum product.

High volume, low margin commodities where the feedstock is a high portion of their costs are quite sensitive to the price of oil. Specialty chemical products, while somewhat sensitive, are by and large more sensitive to supply and demand.

CURRENT RESEARCH

I. NEW CROPS

A. Oil seeds

1. Crambe and Rape

Crambe has been extensively investigated. Its seed oil contains 55-60% erucic acid, which is now imported in high erucic acid rapeseed oil. Erucic acid is used in the production of erucamide, an antiblock, slip-promoting additive for plastic films such as polyethylene. Behenyl amine, the 22-carbon saturated amine from erucic acid, is an effective agent in fabric softeners, emulsifiers and in corrosion inhibitors. Erucic acid can also be used to produce ethylene brassylate which serves as a fixative for perfumes and fragrances, and for making nylons. Crambe oil is also superior to other oils as a mold lubricant in the continuous casting of steel.

Research has shown that crambe is a cool season crop capable of production up to 2000 pounds of seed per acre. The defatted meal has Food and Drug Administration approval as a protein supplement at 4.5% of the diet of beef cattle. Commercial production of up to 2000 acres, according to the United States Department of Agriculture, Office of Critical Materials, has been achieved. Its yield should be 1500-1800 pounds per acre. Assuming a current import value of 40-45 cents per pound for imported rapeseed oil, crambe oil would be competitive if the farm price of seed were 10-12 cents per pound. Approximately 1000 acres of crambe will be grown this coming year in Iowa. The Office of Critical Materials will provide financing to offset any additional processing costs needed by Witco Chemical Corporation of Memphis, Tennesee.

Rapeseed can also be grown in northern climates. It is not as high in eruric acid as crambe. Little research has been done on raising the erucic content of rapeseed. Indeed, the Canadians have bred rapeseeds with very low or zero erucic acid. Nebraska is a border state between the best growing environments for crambe(southern) and those that are best for rapeseed(northern.) A side-by-side comparison of rapeseed and crambe might be recommended. Rape has been approved on an individual county basis for growing on set-aside lands, although it cannot be harvested for its seeds when used in this manner.

Extent of Market: If 100 percent were displaced by domestic sources this would provide a market for 22,000 acres of rape or crambe.

2. Meadowfoam

Meadowfoam was first domesticated at Oregon State University from 1963 to 1983. It is in its third year of commercial production in the Williamette Valley. Significant quantities of oil have been solid in the cosmetic market. Product development and evaluation are also underway in the specialty lubricants area, with market introduction of consumer products expected in 1986. The Office of Critical Materials believes that increased seed and oil yields are fundamental to the development of meandowfoam's economic competitive potential and its entry into high volume markets. The Oregon Meadowfoam Growers Association is seeking a commitment from a large company before it is willing to spread the seeds around the country to insure against local crop failure. Meadowfoam is grown in Oregon as a winter annual but could be a spring crop in the midwest. It may be a competitor for high erucic rapeseed oil.

The current price of meadowfoam oil is in the range of $3.50 to $4 per pound, Prices may decline to approximately $2 per pound within the next 5-10 years if high yielding cultivars are developed and large scale production facilities become operational.

Extent of market: Office of Critical Materials estimates that the market for meadowfoam oil could reach several million pounds of oil per year by 1990.

B. Sweet sorghum

The USDA claims that sweet sorghum produces 2-4 times as much fermentable sugars for alcohol than corn per acre. The energy output-input ratio for sweet sorghum of 7 is much more favorable than the ratio of about 4 for most other possible alcohol feedstocks and there is little soil erosion. The farmer can expect to obtain 9 dry tons per acre of fiber fuel and 4 tons of fermentable sugars, which can be converted to 500 gallons of ethanol at 78% recovery.

Sweet sorghum is being tested in several states as a feasible new crop. The Gas Research Institute(GRI) has developed partnerships with Cornell and Syracuse Universities in New York, Texas A&M in Texas, and the University of Florida at Gainesville for investigations into the use of sweet sorghum in anerobic digestors to produce pipeline quality gas. At current gas prices the production of gas from sweet sorghum is considered uneconomical(i.e. $6-7 per MMBTUs). GRI believes costs can be reduced significantly below that price.

Mankato Technical Institute(MTI) in Minnesota planted 5 sweet sorghum varietites in 1985 and achieved a yield of "greater than 40 tons of green biomass per acre with stalks composed of about 90% sugar juice".[1] All five varieties achieved yields of over 500 theoretical gallons of ethanol per acre and two achieved yields of 650 gallons. Preliminary feasiblity studies indicate that simple field expression and subsequent juice fermentation and distillation to ethanol can yield ethanol at a cost of 92 cent per gallon.(A Florida study reported in 1983 estimated a cost of 81 cents per gallon.) A complete feasibility report is due by MTI to the Minnesota legislature in October 1986. Preliminary indications are that ethanol costs as low as 60 cents per gallon can be obtained. Mankato is investigating the conversion of sweet sorghum to butanol rather than ethanol. Butanol-acetone was fermented from the juice with 91% conversion efficiency.

The University of Nebraska planted sweet sorghum in 1978 and achieved much lower theoretical yields. Bob Ogden at UNL believes part of the problem is that sweet sorghum when field pressed allows the rapid growth of baceria that produce dextrin from the sugars and by the time the juice is taken to the fermentation facilities there is little

[1]Holly, S. M., J.B. Hochalter, Butanol and Ethanol Production from Sweet Sorghum. Demonstration Project. 1985 Interim Report to the Minnesota Legislature through Mn-DEED. January 1986.

sugar available. Mr. Ogden believes that this could be overcome by pressing inside a plant or by pasteurizing the juice quickly, both of which would raise the cost of the final product. It is difficult to store the juice easily, making sweet sorghum processing into ethanol a seasonal proposition and probably therefore a complement to rather than a substitute for corn to ethanol processing.

Extent of Market: Sweet sorghum appears to have the greatest lignocellulosic production capacity of any northern climate crops except for woody grasses. Moreover its high fermentable sugar content makes it a highly competitive source of ethanol. Thus its market as a fiber fuel or for ethanol is significant.

II. New Processes

A. Delignification via hydrogen peroxide

Michael Gould, researcher at the Northern Regional Research Labotatory at Peoria, developed a treatment of straw with hydrogen peroxide which removes 50% of the lignin and makes the 50% that remains totally digestible by animals. George Fahey, animal nutritionist at the University of Illinois, has evaluated its use as an animal feed with sheep and fistulated cows. The process is patented and a license shared by InterOx of Houston, a major hydrogen peroxide producer, and Birk Agriproducts of Saint Paul.

Extent of Market: This market is for specialty feeds and therefore does not fall within the purview of this study. However, such a process might be a useful pre-treatment for material for further treatment by the cellulase enzyme. However, some researchers, such as Dr. Helene Chum of the Solar Energy Research Institute, points out that hydrogen peroxide is some ten times as expensive as dilute acid. The digestibility is very good of the end product but the cost is very high. Therefore the specialty feed sector would be the only possible market, and that would be possible only if a company like InterOx is involved that has an internal production facility for hydrogen peroxide.

B. ethanol cost reduction

1. co-fermentation

Graduate student Michael Whalen at UNL has developed a process for co-fermenting corn and whey wastes. The process uses maltose rather than glucose from corn and lactose from whey. The process can be backfit on any conventional system, although additional storage is needed and there is not yet an independent supplier of the lactose fermenting yeast.

A pilot plant operating in 1985 yielded 3.4 gallons per bushel of corn input. A small commercial plant has been operating in Lincoln since January 1986. The Schneider ethanol plant produces 120-130,000 gallons per year and obtains whey waste from the Beatrice Dairy's cottage cheese plant in the city. Schneider's cows supply milk to Beatrice, effectively closing the loop.

Michael Whalen estimates the process would reduce the cost of producing alcohol by 16.5-18 cents per gallon. This takes into account that there is less feed byproduct, but there is a 6% increase in the protein content of the byproduct.

A report is due by the summer 1986 on the Schneider operation. It will contain recommendations on whey pre-processing by the cheese plant that can enhance the viability of the operation.

UNL is negotiating with a company for a license to the process. The name of the company was not given.

Extent of Market: The ethanol market already uses 250 million bushels of corn in 1985, up from 20 million bushels in 1980 and is expected to increase to 500 million bushels in 1990. The nation dumps 23 billion pounds of whey annually in the US. An equal amount is recovered as whey protein and sold. (Nine pounds of sweet whey is produced per pound of cheese and 6 pound of acid whey for one pound of cottage cheese.) Nebraska produces about 700 million pounds per year of whey waste. The Clean Water Act of 1972 requires sewage charges based on biological oxygen demand, and why requires 40,000 ppm. These charges, and the crackdown on land and lagoon applications by small and medium processors in rural areas, has considerably raised the avoided costs of whey disposal.

A one million gallon per year ethanol plant requires 75 million pounds of whey for the coferementation process. Thus a 10 million gallon plant could be supported with whey wastes in Nebraska alone. Assuming a one billion gallon ethanol output for 1990 the market for whey wastes would be 7.5 billion pounds.

2. enzymatic advances

Renewable Technologies, Inc. of Butte, Montana has developed an enzyme that avoids the need to cook corn starch. Its process needs only the heat naturally produced by fermentation. Mash cooking consumes 20-40% of the overall process energy used in ethanol production. Moreover it is labor intensive and requires capital for the boiler capacity. The RTI process, called ATSH for Ambient Temperature Starch Hydrolysis, has been tested with corn and barley. Ethanol concentrations greater than 90 percent of the theoretical starch-to-alcohol conversion efficiency can be achieved in 48 hours. For existing well-designed, large scale plants(60 million gallons per year), energy cost savings would be 3-4 cents per gallon. For a 1.5 million gallon per year plant, less well-designed, up to 10 cents per gallon cost savings can be achieved. If a new plant is established the savings on new equipment would be in the range of 6-8 cents per gallon.

3. pyrolysis

Pyrolysis is a process of controlled combustion. Pyrolysis of lignocellulosic or cellulosic maerial produces char, pyrolytic oil, water containing water-soluble organic substances, and non-condensible gases. The char is primarily carbon and can be used as a fuel or converted to activated carbon, to producer gas for use as a clean burning gaseous fuel or to synthesis gas for organic synthesis. The major components of the non-condensible gases are hydrogen, carbon monoxide, carbon dioxide, and methane along with minor amounts of the other hydrocarbon gases. The gas can be utilized on-site as a clean burning low BTU gaseous fuel;. The pyrolytic oils are clean burning with heating values approximately two thirds the heating values of fuel oils. There is, however, a great potential for utilizing pyrolytic oils as a source of chemical materials. Experimental data indicates that the oil may contain as many as 200 or more compounds. By changing the amount of air and the combustion rate the kind and quantitiy of these various components can be varied. American Carbon of Atlanta, Georgia is composed of the principal developers who, while at the Georgia Institute of Technology, developed a pilot plant designed for investigating the continuous processing of pyrolytic oils. American

Carbon has sold two pyrolysis plants to Kingsford for making charcoal and is currently targeting municipal sewage systems as a market for activated carbon as they upgrade their treatment facilities. American Carbon estimates that 1100 tons of activated carbon needed per year for a sewage plant of 5 million gallons per day capacity. A minimum scaled plant would provide sufficient activated carbon for a population of 250,000.

Pyrolysis plants are less sensitive to scale economies and to feedstock costs than to the selling price of their product. Such a plant appears profitable when the feedstock is less than $12 per ton when selling the char to conventional sources at $130 per ton. Assuming sales at more than $300 to the activated carbon market the feedstock price can be over $20 per ton. Sales of pyrolytic oils for specialty chemicals is another high value added market. One Georgia company is currently importing pyrolytic oils to make specialty chemicals.

III. NEW PRODUCTS

A. Calcium Magnesium Acetate

The use of crushed rock salt as a de-icer causes billions of dollars of damage annually due primarily to corrosion to cars and bridges, damage to underground electrical distribution systems and pollution of groundwater. The most attractive alternative appears to be calcium magnesium acetate. The Federal Highway Administration is currently carrying on nationwide tests under the National Cooperative Highway Research Program. New York state is exploring ways to economically produce CMA using natural resources within their state. Michigan has undertaken a comprehensive corrosion study using CMA. Iowa is producing CMA-coated sand for use in their state. In a test in 1982-83 Iowa found the de-icing performance of CMA/sand equal to salt/sand when applied at equal rates in the presence of traffic. When traffic was absent the CMA/sand mixture was slow to react and did not perform as well as the salt/sand mixture. Overall nationwide testing concludes that CMA operates at similar temperatures as sodium chloride. However, it works best when applied early, must be applied in larger amounts, and creates dust. Nebraska's road department has done some laboratory and parking lot tests and found the results "disappointing".

Crushed rock salt costs about a penny a pound. Calcium magnesium acetate made from natural gas converted to methanol and then to acetic acid and adding other elements costs 30-40 cents per pound. If the C6 sugars from corn are used the cost is in the 19-27 cent range. Using C5 sugars or other low cost sources of sugar(e.g. from waste streams of conventional paper pulping or from whey wastes) could lower the price to the 10-15 cent range. New York State Energy Research and Development Administration(NYSERDA) estimates that processing costs are 7-15 cents while Gancy Chemical Corporation estimates that costs aside from that of buying or producing acetic acid are 5.5 cents per pound. The quality of acetic acid is not particularly important for de-icing so the fermentation route to crude acetic acid is very attractive.

NYSERDA estimates that a 14 cent per pound CMA cost would be cost-effective for its highway and public works department because of reduced maintenance on bridges. NYSERDA estimats that the total cost of using salt, including corrosion to vehicles and pollution damage, is about 80 cents per pound.

Gancy Chemical Corporation, under contract with NYSERDA, is building a pilot production facility. This plant will probably use acetic acid made from natural gas. Dynatech, based in Cambridge, Massachusetts, is exploring a production facility to make acetic acid from biomass. The University of Georgia Research Foundation Inc. has recently developed an enzyme that increased acetate yields by 300 percent.

CMA can also be produced through a non-fermentation route. The South Dakota Department of Transportation has a patent for cooking sawdust or wood wastes with dolomitic lime to produce calcium and magnesium salts. It claims the mixture is better in some respects than CMA for deicing.

Extent of Market: The nationwide use of crushed rock salt is about 10 million tons. Nebraska Road Department purchased 23,100 tons of crushed rock salt in 1985 at $17.20 per ton. The state used 1090 tons of calcium chloride(used at very low temperatures) at a cost of $201 per ton. (NYSERDSA's Larry Hudson belives that calcium chloride may be replaced by CMA in solution). One pound of biomass produces 1/2 pound of CMA, asyming a 50% loss to CO2(although NYSERDA is working on bacterial strains that have significantly lesss CO2 production. Thus the estimated market is 20 million tons of biomass. The market within Nebraska would be about 47,000 tons of biomass which would provide a market for 7000-10,000 acres.

The substitution of biomass for rock salt does not displace fossil fuels. However, the substitution of biomass based acetate for natural gas based acetate does. One of the attractions of CMA is that it requires relatively low quality acetic acid. Therefore this can be made from biomass for the CMA market and then the acetic acid can be upgraded to compete for other chemical uses.

B. Starch Based Plastics

1. biodegradable plastic film

NRRL holds several patents for the development of blown films from starch. These films must have over 30% starch to have biodegradable properties. NRRL has blown films with 45% starch. Usually the mixture is 40 percent starch, 20% ethylene-acrylic acid(the expensive part of the mixture) and 40% polyethylene.

Imperial Chemical Industries of England has also fed sugars to alcaligenes eutrophus to synthesize beads of polyester. It has manufactured several tons of polyester in 1985 The bacterial product is called Biopol. It is indistinguishable from polyester derived from oil except that it is biodegradable.

Several companies have approached the federal government to ask for exclusive license to this process. However, no licenses have been signed. The Northern Regional Resource Center has shifted more resources into an investigation of degradable starches. According to Felix Otey, patent holder and director of the project at NRRC, the major thrust is to develop combinations that reduce the degradation time without compromising the mechanical properties.

Extent of Market: There are 60 million pounds per year of polyethylene used for the agricultural mulch market alone. It costs over $100 per acre to take up the film at the end of the growing season, giving a competitive edge to degradable films. On the market are petroleum based degradable plastics that degrade when exposed to sunlight's ultraviolet rays. However, this does not degrade that part of the film that is buried and therefore is not as effective as the starch based plastic.

2. encapsulation

1.5 billion pounds of chemicals are used to control weeds and insects each year. Most don't stay where they are applied. Currently a mixture of clay and chemicals is used to accomplish controlled release. A matrix of starch can do the same, reducing chemical use by 10-90% and runoff by a larger percentage. Lactic acid based encapsulation is already used for slow release capsules in medicine, but the price is not competitive yet for agricultural operations. Starch and water is mixed, giving a thick dispersion and then herbicide is added. This can be made into a granule or into a spray. Field trials with Treflan, a broad leaf weed killer was done beginning in 1980 with Purdue University and proved successful. The Northern Regional Research Center in Peoria has a number of patents on the process. According to Doug Campion at the National Technical Information Service several companies have been granted exclusive or shared licenses to various encapsulation formulae. Pennwalt, headquartered in Philadelphia, has an exclusive license to one. The other, more promising patent was awarded on a shared license basis to Hopkins Chemical, Ilinois Cereal Mills, Dupont and Stauffer Chemicals in June 1984. Exclusive licenses are granted only on the basis of an agreed-upon development plan. Each company must submit an annual report discussing the amount invested to-date and progress. These reports and the development plan are confidential. However, the fact that licenses have been granted means that investment is ongoing in this area and that products should be close to commercialization.

A major project is now going on at Purdue to deal with spray applications. About 80 percent of the total amount of pesticides and herbicides is applied as sprays and 20 percent as granules, but granules are increasing because of ease of handling.

Dr. Charles Walker at UNL has used corn flour to encapsulate pesticides, with funding by the Nebraska Corn Board. This is cheaper than corn starch. Preliminary investigations appear to show that it works better on insecticides than other processes.

Extent of market: William Doane of NRRL estimates a potential market for one billion pounds of corn, assuming one bushel of corn equals 32 pound of starch.

3. super-absorbents

In 1975 the NRRL developed a patented process for copolymerizaton of starch and orlon. It absorbed 300 times it weight in water. Dubbed the super slurper, the product has been on the market for various applications(e.g. a gel on plant roots) for several years. Since then NRRL has developed patents for applications of 1 to 3 starch to synthetics all the way to 3 to one synthetics to starch. Normal ratio is 1:1.

Several companies have been provided non-exclusive licenses for the process and at one time some 40 companies were producing it. Currently there are three commercial producers:

Super Absorbent Company
Route 3
PO Box 342
Lumberton, NC 28353

Grain Processing Corporation
1600 Oregon Street
Muscatine, IA 52761

Polysorb, Inc.
W. 1000 Silver Road
Smelterville, ID 83868

A major new market is for diapers. Proctor and Gamble announced in February 1986 that it would be selling a superabsorbent diaper. The material is to be obained from Sanyo, a Japanese company which obained a modified patent based on NRRL's work in the late 1970s. Reportedly Grain Processing Corporation is supplying Sanyo the material, which is then modified by Sanyo. No American company is currently producing the material in a grade acceptable to the soft goods market. Dupont has recently developed a superabsorbency material based on petroleum.

Extent of Market: William Doane of NRRL estimates the superabsorbency market for diapers alone to be about 400 million pounds a year. The material can also be used as a gel to surround plant roots, to dehydrate ethanol, and to reduce soil erosion. One hundred applications have been identified to date.

4. wheat abrasive

Wheat has been used by the Nebraska Public Power Association to substitute for sand to clean electrostatic precipitators on coal fired power plants. The plates and wires have wrappers on them to keep them clean but over time a coating of fly ash occurs. Traditionally sand blasting is used for cleaning but the contractors tend to clean so thoroughly as to abraise away some of the metal. Wheat is hard enough to take off ash but soft enough not to be abrasive to the metal. Each of the 650 megawatt units of the Gentleman Station at Southerland is cleaned by wheat. The contractor simply subsititutes wheat in its hopper for sand. The cost of cleaning is the same, in part due to the depressed price of wheat and in part due to the lower transportation costs because wheat is lighter. About 25,000 bushels, the equivalent of 900 acres of wheat is used for this purpose.

Extent of market: Since this process displaces sand, but not petroleum it does not meet the objectives of this study. It is also a niche market. The other two coal fired power plants in Nebraska have either a baghouse or cyclone burner on the boiler. Thus there is much less need for cleaning. Also the New Federal Performance Standards require a scrubber, which wouldn't require this kind of cleaning.

5. soy oil for grain dust control

Using oil to coat grain in elevators to reduce the potential of explosions is a new market. The treatment lasts up to a year. There is a need to spray the grain only once, no matter how many times it is moved. The process eliminates the current use of fans, etc. to keep the dust down, a process that is quite energy- intensive.

Soy oil competes in this market with mineral oil made from petroleum. Already 100 elevators are using mineral oil; ten are using soy oil. The treatment is one million parts grain to 200 parts soy. One gallon treats 19 tons of grain. It can be used to treat wheat, corn and sorghum.

Soy oil has several advantages over mineral oil. Since it is edible there is no upper limit on treatment. Therefore one operator need not worry about its overuse. Soy oil is considerably cheaper than mineral oil. However, whereas white mineral oil can be delivered in 55 gallon barrels, soybean oil does not yet have such packaging .

The market is slowly opening up. One reason for the slow growth is a pending patent suit by a company that says it owns the patent on all oil applications for grain dusting and is asking for a royalty. Also many elevators will not use oil until the Federal Grain Inspection Service(FGIS) provides approval. FGIS has already approved grain from the 100 elevators using oil, but has not given blanket approval. The petroleum industry has also warned that the use of soy oil causes rancidity, although studies by the American Soybean Association disputes these assertions.

Extent of Market: There are some 10-12 billion bushels of grain stored. The market for soy oil is thus 15-18 million gallons, equivalent to the yield of about 10-14 million bushels or about 300,000 acres.

6. binders

Dr. Milford Hanna of the agricultural engineering department at UNL, funded by the corn and soybean growers association, has made adhesives for particle boards from alcohol wastes. Kamterter, Inc. of Lincoln is making a binder out of ethanol stillage and by-products from corn sweetener process. Minimal processing yields binders that can be used to make cellulose fuel cubes for municipal solid waste. Yield is 15 pounds of binder per bushel. It is water resistant. According to John Eastin, vice president of Kamterter, this product could add $2 to the value of a bushel of corn, although it displaces some of the feed value. Taking into account the reduced value of feed the net benefit is $1.50 per bushel.

With more extensive processing a resin can be obtained for plywood and particleboard.

Extent of Market: Eastin estimates a large market for national municipal solid waste. However, most municipal waste is currently being incinerated on-site and 75-90% of current contracts are for this purpose. This would negate the market for fuel cubes. Eastin also estimates a very large market for building supplies.

7. Corn Protein

Charles West of Resins Research Laboratories, Inc. of Newark, New Jersey claims to have converted corn protein into an engineering plastic. Although apparently not a near-term commercialization product the conversion of proteins into industrial plastics may be important given the surplus in the animal feed market and the fact that most byproducts of conversion processes(e.g. corn to ethanol) target animal feeds. Although there is currently a surplus in starch, alternative uses of protein might become important in the early nineties.

Extent of Market: Unknown.

8. Furfural and lignin

While this report focusses on near term commercialization, in some instances a specific process change could provide a dramatic shift in economics. This is especially true for lignocellulose. This section addresses the impact of co-product credits for furfural and lignin.

a. Furfural can be made by the acid degradation of five carbon sugars or hemicellulose. Furfural is used in petroleum refining as a selective solvent and is reacted with phenol to produce thermosetting resins. It is also sold as a chemical feedstock to produce furfuryl alcohol and tetrahydrofuran(THF). The present market for furfural is only about 140 million pounds, primarily because of the very high price(about 65 cents per pound). Quaker Oats is the only domestic producer of furfural and controls two-thirds of the world market. The incremental cost of furfural co-production with ethanol from lignocellulose has been estimated by SERI at 5.5 cents per pound. A 1981 study by MITRE estimated that at 30 cents per pound markets of up to 2 billion pounds per year for furfural would open up. A SERI study found that styrene and butadiene cannot be produced competitively from furfural even when furfural prices were set at zero. However, designs for adipic acid, maleic anhydride and butanol generated selling prices competitive to hydrocarbon processes when furfural was priced at 29,10 and 8 cents per pound. Adipic acid has a relatively large market and a very high value and has the highest potential benefit of all chemicals that could be produced from hemicellulose. Nearly all adipic acid is used in the manufacture of nylon 6.6. Maleic anhydride is another large market material that is used in unsaturated polyester resins used for boat construction, fiberglass reinforced tanks, piping and electric insulation. The commercial process presently makes maleic anhydride from benzene, butane and butenes. A speculative route would produce maleic anhydride from furfural via a furan intermediate process. THF is used as a solvent for polyvinvyl chloride polyurethane and other polymers. It was first made from furfural but recently it is made from petrochemical feedstocks.

SERI estimated in 1983 that a net credit of 15 cents per pound of furfural would reduce the selling cost of ethanol from $160 to about 80 cents per gallon. The available markets for furfural at a price of 15 cents per pound would be saturated with ethanol production from lignocellulose of 900 million gallons.

Extent of Market: Approximately 3 billion pounds, the equivalent of the furfural production from a wood-to ethanol plants with a capacity of 450 million gallons of ethanol

b. Lignin serves a stiffening agent that laminates individual carbohydrate fibers together in wood. It contributes approximately 16-33 percent by weight to wood. The two structural features that distinguish lignin most clearly from the rest of the structural components of wood are its phenolic character and the fact that it is an amorphous, complex polymeric structure. 1.5 billion pounds of lignin were used in 1983 for non-fuelpurposes. The major markets for lignosulfonates and sulfonated Kraft lignin are as a component in drilling muds, a binder for animal feds, in construction materials such as gypsum board, cement and concrete admixtures, and as a an agent in dust control and soil stabilization. The average selling price in 1984 was 15.5 cents per pound. The major producer of sulfonated Kraft lignin is Westvaco.

The Federal Highway Administration has sponsored several studies on asphalt extenders or asphalt substitutes. Only laboratory tests have so far occurred, but they have been positive.

SERI analysis concluded that via steam explosion of wood it would csot about 1.6 cents to recover lignin. The fuel value of lignin(based on $1.97/MMBTU cost of coal) is 2.2 cents per pound. In fact, the cost of lignin isolation as a boiler fuel would be more competitive because lignin could be concentrated to 50-70% solids rather than the 90% solids used in SERI analysis.

Extent of Market: SERI estimates a potential market of 13 billion pounds per year demand , which would support a production capacity of about 3 billion gallons of ethanol. The co-product credit would range from 30 cents to $1.50 per gallon, with a weight average co-product credit of 60 cents per gallon ethanol.

One word of caution about market estimates of co-products from the conversion of lignocellulose to ethanol. As Table 10 indicates, the disparity between the small chemical markets and the vast fuel markets means that the former will be saturated even if lignocellulose were to meet the present (1986) ethanol market. Is is quit conceivable that the demand for these chemicals will grow substantially. The demand for petrochemicals has vastly outpaced the demand for fuel in the past ten years. Most of this demand is for substitutes to other minerals, such as iron or sand.

TABLE 10

Co-Product Saturation Rate from Lignocellulosic Based Ethanol Production[2]

Co-Product	Ethanol Volume to Saturate Market(10^6 gal/y)
Furfural	20
THF	18
Furfuryl Alcohol	9
Citric Acid	22
Lactic Acid	3
Adipic Acid	170
Acetone and n-butanol	348
Maleic Anhydride	53
Ethanol(fuel)	10,870

IV. DISPLACING FERTILIZER

The principal focus of this study was to identify new markets for agricultural materials. However, fossil fuels can be displaced through conservation or other efforts. A good example of such research in Nebraska is that undertaken by Kamterter, Inc. of Lincoln.

[2]Linda L. Gaines and Michael Karpuk, Fermentation of Lignocellulosic Feedstock: Product Markets and Values, Argonne National Laboratory, no date, Mimeo. Argonne, IL.

Kamterter has six patents on the production of ammonium nitrate from anhydrous ammonia under low pressure. Ammonium nitrate is useful for conservation tillage since much less can be applied per acre and much less runoff occurs. Up to 40 percent of nitrogen applications, all of which are derived from natural gas, can be saved. The production process of ammonium nitrate is highly energy intensive. Twenty-two thousand Btus are required just to get nitrogen to ammonia and then high pressure is needed to make ammonium nitrate. The energy cost of applying 200 pounds of nitrogen per acre is more than 5 million Btus. John Eastin estimates that the low pressure process can reduce the cost to the farmer by three cents per pound and can also increase dealer profits. Moreover, the process can be accomplished on a very modeset scale, a minimum of 200 pounds per hour as opposed to an average of 50 tons per day in conventional plants. Thus the value-added in the process might be captured by the state economy.

STRATEGY MATRIX

Table 11 reflects our conclusions based on our investigation of current research. This table rates each of the crops, processes, and products that were deemed to meet the objectives of this study against five variables: 1) the value of the product, 2) the market potential, 3) the sensitivity of the product to the price of oil, 4) production scale economies, and 5) infrastructure problems.

These ratings are, of course, judgmental. For example, calcium magnesium acetate, when competing against crushed rock salt, is a very low value commodity. However, if the community realistically evaluates the social and environmental costs of using salt then the competitor for de-icing may be natural gas based acetic acid and not salt. CMA might then be viewed as a medium value commodity. The market for salt is moderately large, possibly 10-25 million tons per year. The sensitivity to the price of oil is relatively low in that the price of oil directly influences the price of natural gas and the price of natural gas would have to fall still further than its present price to be competitive with biomass in making acetate. The production of CMA can be done on a relatively small scale. The infrastructure problems are rated as high because each state highway and public works department must first test the product and then must change the way it normally applies de-icing materials.

TABLE 11

Strategy Matrix

Opportunity	Product Value	Potential Market	Oil Price Sensitivity	Scale Econ.	Infrastructure Problems
CMA	Mod.	Mod.	Low.	Low.	High.
Crambe	High	Low	Mod.	Mod.	Low
Pyrolysis to activated carbon/oils	High	High	Low	Mod.	Low.
Sweet sorghum for ethanol	Low	High	Mod.	Mod.	Low
soy oil for dust prevention	Mod.	High	Low	High	Low
Starch based					
plastics	Low	High	High	High	Low
encapsulation	Low	High	Mod.	Mod.	Mod.
absorbents	Mod	High	High	Mod.	Low.
starch-to-ethanol					
ATSH	Mod.	High	Mod.	Mod.	Low.
co-fermentation	Mod.	High	Mod.	Mod.	Low.
lignocellulose-to-ethanol*					

*Emerging technology

INFRASTRUCTURE

To accelerate the commercialization of the research discussed above Nebraska should take advantage of existing programs within and outside of the state.

1. Federal

There is increasing evidence that the vast agricultural surplus is forcing the federal government to focus on new market development for existing crops and new crop development. The Office of Critical Materials, for example, is actively promoting and modestly funding kenaf and crambe projects. The Northern Regional Research Center has recently shifted resources into near-term commercialization projects related to starch. The Secretary of Agriculture's recent willingness to use corn inventories to encourage the ethanol market may be an excellent precedent for the use of inventories to provide inexpensive feedstock for a number of commercial applications.

The set aside program may offer opportunities for the use of this land for testing new crops and possibly for new harvest techniques. Already individual counties in

Nebraska have been approved for growing rape, although they must use this for grazing or haying purposes. Conceivably high erucic crambe could be used to test growth rates even if it were not used for grazing or haying. Although set aside lands cannot be used for commercial purposes, it may be conceivable that their harvest could be used for experimental purposes where the final product was not intended for commercial distribution(e.g. testing oil seed processing or juice extraction techniques).

The Agricultural Stabilization and Conservation Service provides funding for soil conservation programs. Conceivably this could create an internal market for some new materials. For example, one of the uses of the superabsorbency is to reduce soil erosion.

2. Trade Associations

The American Soybean Association and the National Corn Growers Association, both based in Saint Louis, have targeted new markets for their respective commodities. The NCGA has established a task force which includes major corn purchasers to investigate how to accelerate the commercialization of new products. They have met, for example, with Coca Cola which has expressed interest in investigating the use of corn-based plastics for soft drink containers.

The obstacles to the use of soy oil for reducing the risk of dust explosions might be overcome with state assistance. This could be done by demonstrations or by persuading grain storage facilities in Nebraska to purchase these oils.

3. Other States

Several state energy offices throughout the country are funded via checkoffs on electric consumption. Thus they have significant resources. These include the New York State Energy Research and Development Administration and the California Energy Commission as well as the Alternative Energy Corporation of North Carolina. These are funding modest to significant investigations of biomass. NYSERDA has expressed an active interest in participating with Nebraska on joint projects and has a history of contracting outside of the state for services.

4. Nebraska Resources

The University of Nebraska is a key development agency. It has had in place for many years a system of licensing faculty-originated patents: one third of the royalty payments goes to the individual,one third to the department, and one third to the university. In 1985 $150,000 in royalty revenues was received by the University.

In January, 1986 the University of Nebraska Foundation established the Nebraska Technology Development Corporation. It has a two-fold purpose: 1) to take technology developed within the university and move it into the marketplace, and 2) to act as a focal point for the occasional inventor from outside the university community. Lee Schroeder and Associates of Lincoln is currently developing a recommended structure, funding level and operating strategy for the new Corporation. Its report will be submitted in August 1986

In 1986 the Nebraska Research and Development Authority was established with a $2 million appropriation from the general fund. Approximately $250,000 will be used to hire staff and for institutional development. $1.75 million will be used for applied research. (This money could be used for venture capital or equity investments or loans.)

The state has shifted $1 million from the Community Development Block Grant program to provide for start-up capital for companies. It is expected that by January, 1987 the Authority will entertain proposals.

The Nebraska Industrial Development Authority has been in existence for several years. It has bonding capacity for land acquisition and physical asset financing.

Research moneys are available from the various crop boards. In 1985 approximately $1.3 million was spent, of which $900,000 to a million was allocated by the corn board. A very small percentage of these funds were spent to create new industrial markets for their products.

Finally, there is the oil overcharge money, a one time payment to the state of Nebraska, part of which could be used for agricultural development where the direct result was the conservation of petroleum.

An interesting collaborative situation, focussed on similar objectives as those of Nebraska, is currently taking place in Illinois. It is still embryonic but deserves some attention. In Peoria an informal partnership has developed between the local utility, Central Illinois Lighting Company(CILCO),the City of Peoria and the Northern Regional Research Center . Peoria has lost 20,000 jobs in the last six years. An economic analysis of its resource base, done by the Economic Development Council, identified NRRC as the key technology development center and the available agricultural infrastructure of the area as an excellent potential resource. Peoria is now actively supporting an amendment to the Stevenson-Wydler Act that has passed the House and is in Senate committee. This amendment would allow national laboratories to contract with private businesses. CILCO has invested $15 million in a venture capital fund which will target growth opportunities spinning out of NRRC and locating in the city or surrounding area. The service area is about 250,000 people.

CILCO views this program in part as a way to increase its energy sales. This is not within the program objectives of the Nebraska Energy Office. Moreover, Nebraska does not have private utilities. However, if the Nebraska Public Power Association were to finance economic development that both increased demand for electricity and displaced the use of fossil fuels, the objectives of the Nebraska Energy Office could be achieved.

RECOMMENDATIONS

The agricultural base of Nebraska offers enormous opportunities to develop new products from existing crops and to develop new crops. This can reduce Nebraska's dependency on non-renewable inputs, increase the stability of its economy by diversifying its markets, spur new scientific endeavors in rapidly growing sectors(e.g. waste utilization), and create an export market for this knowledge.

We recommend:

A. Production

1. Crambe and sweet sorghum be targeted as new crops. Crambe should be grown alongside rape to evaluate which is better for Nebraska. Sweet sorghum should be viewed for both maximizing biomass per acre and for ethanol production.

2. The set-aside program and soil conservation program should be evaluated for possible opportunities to supply land while providing the farmer with a revenue.

B. Processing

1. Pyrolysis, especially as related to the activated carbon market for upgrading sewage plants, should be explored with contacts made with American Carbon in Atlanta, Georgia.

2. The program should focus on using waste products(e.g. co-fermentation techniques, whey into CMA) because here there is an avoided cost for the community which can be factored in by the state and local governments.

3. Starch based encapsulation, super-absorbency and degradable plastics markets should be explored, with contacts made with the various companies that have exclusive or shared licenses from the USDA.

4. Nebraska should closely monitor the work going on in lignocellulosic conversion to ethanol.

C. Infrastructure

1. Collaborative programs be established with NYSERDA, the Offce of Critical Materials, the National Corn Growers Association, the Oregon Meadowfoam Association and other interested agencies

2. An integrated approach be used to accelerate commercialization. For example, if set aside money can be used to supply land, part of the oil overcharge money might be used for training and educational purposes. The Nebraska Research and Development Authority can provide applied research money and both the NRDA and the Nebraska Technology Development Corporation can provide seed and venture capital. Private venture capital and the cooperation of private companies must also be involved.

It may be useful to contact Genexus(President Charles Fishel, 3000 Sand Hill Road, Menlo Park, CA 94025). It is the parent company of the Utah Innovation Center, one of the first university related innovation centers. Genexus is establishing a network of profit oriented innovation centers, mostly in association with universities, and a network of venure capital to fund these ventures.

3. The Nebraska Public Power Association should become a partner in development. The twin goals of local economic development, a healthier balance sheet for Nebraska utilities and the displacement of fossil fuels are compatible.

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