Ethanol Production From Municipal Solid Waste In Nebraska

A General Feasibility Study

Prepared for the
Nebraska Energy Office
by
Economic Research Associates
Lincoln, Nebraska

April 1994

TABLE OF CONTENTS

EXECUTIVE SUMMARY

1. Two public policy goals coincide to support further investigation of the feasibility of a demonstration-scale plant for the conversion of municipal solid waste to ethanol in Lincoln and Lancaster County. They are:

   a. The City of Lincoln "owns" a large quantity of municipal solid waste for which it is responsible. It also operates a fleet of cars and buses and is the site for a large part of the fleet of vehicles of the State of Nebraska.

      The City is now in the process of considering how it will deal with the waste for which it is responsible. It should consider the inclusion of a waste-to-ethanol demonstration plant in its Solid Waste Management Plan as an alternative to burial or sale on the recyclables market.

   b. Throughout the United States, progress toward full-scale production of waste-to-ethanol has stalled at the pilot stage. Construction of a carefully designed demonstration plant in Lincoln could contribute significantly to national energy policy.

2. In considering such an effort, however, it must be understood that ethanol-from-waste is experimental at the demonstration stage and any ethanol plant will be a customized, site-specific application with many unknowns.

Technology

3. It appears that there is more than enough cellulose waste to provide feedstock for a 50- to 100-ton-per-day demonstration-scale ethanol production facility plant in Lincoln and Lancaster County.

4. Collection of cellulose-containing wastes, however, is problematic. At present, there is no comprehensive policy on collection of recyclable waste in Lincoln. The direction the City takes in solid waste planning will be important to the consideration of a demonstration-size ethanol production facility in Lincoln/Lancaster County. The City is in a position to build upon the success it experienced in changing the behavior of the community following a landfill ban on yardwaste.

5. Taken all together, the total current use of ethanol by City buses and State cars is about 311,650 gallons, about 40% of the lower range of production estimated from a waste-to-ethanol demonstration plant. These figures, however, represent constrained use during a time when ethanol is considered an expensive fuel by those who buy for and operate public fleets. Because of price, there is currently a detectable bias against use of ethanol among those who deal with it every day in public fleet management.

6. If public entities in Nebraska were to make a firm, sustained choice to maintain and increase the use of renewable fuels in all buses and to continue the conversion of automobile fleets to a higher proportion of ethanol use, over time, a match between production and usage at the demonstration size emerges. Such evolving production and use targets could be matched over time as governmental fleets are replaced and the City's collection and landfill policies mature.

7. Because the economic feasibility of the proposal explored in this study rests on the City's and State's continued and increased use of ethanol fuels in their own fleets is important. Thus, the choices made by those who make public policy and those who specify and operate public vehicle fleets is important.

8. By rule of thumb, the range of capital costs for a waste-to-ethanol plant in Lincoln ranges from $11 to $33 million. Engineering estimates made in 1983 of a specific demonstration-size facility placed the cost then at $22.6 million. This range should be regarded as establishing a ballpark only.

Operations

9. Operation of a demonstration-size waste-to-ethanol plant may be economically positive under the special conditions that exist when the producer has a special obligation for the disposal of a substance which, if not further processed, represents an additional production cost.

10. Analysis requires much more than incomplete and price-driven calculations which all too often represent the state of the art in benefit/cost assessment of public projects. Only a full feasibility study with a specific designs and sites can return the specifics on operational funding under these conditions. Development of full-costing concepts, with special attention to public sector economics, must be a part of any decision to move ahead with further analysis. Qualifications on this basis should be a selection criterion for professionals engaged to move this project ahead.

11. The economic analysis of a demonstration-size waste-to-ethanol facility should include the direct and indirect effects of the project on the economies in which it operates, including the effect of planning and construction expenditures and on-going operations. The economic impact should include at least:

a. Sales Output--calculation of the full effects of all direct and indirect purchases related to the project.

b. Wages and Salaries--calculation of all the direct and indirect wages and salaries due to the project.

c. Jobs--calculation of all direct and indirect employment due to the project.

d. Value Added--calculation of the impact on the Gross State Product.

e. Fiscal--calculation of the impact on the public sector (taxes and fees, for instance).

All calculations must include "substitution" effects, meaning they should be the net difference between expenditures within the defined economy and expenditures outside the economy.

12. Such full costing analysis between the costs of business-as-usual and alternatives should underlie not only the feasibility of this project but all trade-off decisions related to solid waste management and alternative energy investments.

13. Project design should include at least an examination of the beneficial effects of transferring ownership from the public to the private sector after operations become stabilized. In this case, the cost of demonstrating the technology supports a research and development role for the public sector because public entities are uniquely positioned to benefit from the plant outputs, reducing the high cost. After the period of high initial risk, however, a greater good may be served in the community by selling the facility to private ownership. This secondary goal, however, should be planned from inception for best overall economic results.

Environmental

14. This project should be built with the costs of environmental protection fully integrated as a "cost of doing business." Rather than incurring the cost of evasion and avoidance, the plant should integrate the known environmental standards and, to the greatest extent possible, leave flexibility for the changing demands of the future.

15. Known environmental standards exist in the following areas of likely concern to plant designers:

a. Site preparation
b. Feedstock processing
c. Boiler operation
d. Cooling water systems
e. Distillation
f. Liquid discharge from processing
g. Storage and transfer
h. Residue incineration

16. If Lincoln continues to grow, if environmental standards continue or increase, if there is no change in the amount of material that comes into the community to be used and ultimately disposed, there will be an impact of continued landfilling.

In addition, there will be an impact on the shape of the city if more intense processing of waste occurs on or near the landfill site or in a new location. There will be a strong impact on the City socially if businesses and individuals are asked or required to participate in sorting of waste, prior to pick-up.

17. Ultimately, the impact on the City is driven not by an ethanol project but by the forces of commerce which bring materials into the City's solid-waste jurisdiction. Though it is typical that only the variable costs of a new proposal such as the ethanol production envisioned in this study are considered--and often rejected--this project should be seen as just one of the many pieces of the puzzle of disposition of materials imported into the area as a part of ordinary commerce.

Political

18. "Politics," in this case, is defined as presenting the case for a full feasibility study to City management, at least the Mayor and City staff, and to the City Council, as potential public investors and beneficiaries.

19. Such a plan should be well thought out. It should anticipate and meet the concerns of management. It should be complementary to existing goals and plans of the City. And, without question, it will have to include supportive funding.

All too often, ideas come forward to City policy makers on the basis of technical strength or policy values alone. In both cases, only part of the planning job is done.

20. Because the day-to-day managers of most public entities, as opposed to elected officials, feel they are under stress merely to meet the already defined needs of the day, new and different ideas, regardless of merit, are generally greeted with concern. Sooner or later, these managers are likely to react negatively, in private, if not in public, to any proposal like the one in this study. This is only one of many meritorious proposals for change that many long-time City managers have seen come and go. In the experience of Economic Research Associates, most die from skepticism and apathy, not outright opposition.

21. There has been no instant opposition to considering the possibility of a waste-to-ethanol facility in Lincoln. On the other hand, little excitement has been revealed. The Nebraska Energy Office must examine its commitment to this project and should expect to make a focused, concerted effort over many months if it wishes to make this contribution to renewable fuels development in the United States.

The Next Step

22. The Nebraska Energy Office should consider whether it wishes to focus on this project of sufficient merit to dedicate itself to being the primary engine behind its accomplishment. The Energy Office should expect to take upon itself the role of chief financial broker and participant for the project if it wishes to see progress.

a. After commitment, the next step is a full feasibility study. Economic Research Associates recommends a contract which provides for a team of both engineering and economic analysis experts working as one at every stage of the study.

b. The study should produce site-specific recommendations based on examination of all reasonable alternatives for meeting project goals. The study would specify at least construction, operational and marketing variables which meet the project constraints outlined in this study.

c. The Energy Office should draw up a special list of potential bidders on any such feasibility study which requires demonstrated competence:

--in full costing of public sector economics as specified in this study

--in actual participation in the design, construction and operation of waste-to-ethanol technologies.

GLOSSARY

Most of the literature on and around the topics of waste and ethanol production are written by technicians and engineers for technicians and engineers. These writings assume that the reader brings a degree of technical training to the work and a basic understanding of some chemical and physical processes at the molecular level.

This glossary is offered to give other general readers a passing familiarity with the most basic terms and processes in the conversion of municipal solid waste to ethanol.

Bench-scale Technology

A reference to laboratory production models. This stage of development is one step beyond theoretical calculations and written plans. The stage which follows is the pilot stage in which production may increase by 100 fold.

Biomass

Plant materials and parts of city and industrial waste that contain plant materials.

Cellulose

In chemical terms, a polymer of glucose, cellulose is more familiarly known as the "woody" part of plants. Through ordinary processes, cellulose can be chemically broken down into sugar molecules that can then be recombined through fermentation into ethyl alcohol or ethanol.

Cellulosic Biomass

A more specific reference to that biomass--nearly all--that contains the natural sugar molecules which comprise cellulose.

Demonstration-scale Technology

A reference to small-scale production that is 50 to 100 fold larger than the pilot. In waste-to-ethanol production, this would be a facility that uses 50 to 100 tons of feedstock per day. The stage which follows, with a 10 to 20 fold increase in production is the full commercial stage.

Ethanol

Ethanol or ethyl alcohol is form of alcohol that can be used straight or mixed with gasoline as a liquid motor fuel.

Lignin

In chemical terms, a polyphenolic material, closely associated with naturally occurring cellulose. Lignin plays a role in holding cellulose molecules together. The hold of lignin must be released in order to turn cellulose into sugar for fermentation.

The lignin content of cellulose feedstocks is a significant factor in ethanol production because it stands as a chemical barrier to the breakdown of cellulose that must occur. After chemical separation, lignin becomes an energy-rich residue or by-product of ethanol production with use as a combustible solid fuel.

Lignocellulosic Biomass

A specific term which refers to the presence of cellulose (mostly, six-carbon sugars in a molecule chain), hemicellulose (mostly five-carbon sugars in a molecule chain) and lignin in biomass.

Municipal Solid Waste

In the technical language of waste, "municipal solid waste" is everything that local public entities collect from homes, businesses and manufacturers for disposal. It includes a large amount of paper with a varying content of cellulose; garbage (sometimes called wet waste) which includes a large amount of cellulose-containing food waste; yard waste, metals, plastics, appliances, tires and chemicals. Municipal solid waste does not include liquid wastes (sewage), although treated sewage may be used with yard waste and grass clippings (part of solid waste) in composting.

Pilot-scale technology

A reference to relatively small-scale production that is beyond laboratory or bench-scale work. In waste-to-ethanol production this could be a production facility handling about 1 ton of waste feedstock per day. The stage which follows is the demonstration stage where an increase of 50 to 100 fold in production to demonstration could occur.

In This Work

All the terms for describing things with cellulose in them will be replaced with the simpler, albeit less technically precise, term "cellulose," or "cellulose-containing waste." Municipal solid waste will be referred to as "waste."

The reader who wishes to study more in this area should expect to take some time out to become comfortable with the many technical terms and their acronyms.

I. The Research Design

Economic Research Associates was engaged by the Nebraska Energy Office to continue a pre-feasibility inquiry into the possibility of any reasonable and beneficial prospects in the state of Nebraska for conversion of municipal solid waste to ethanol. In the first phase, Economic Research Associates applied some gross formulae to estimates of the amount of paper in the waste streams of Nebraska's two largest cities--Lincoln and Omaha--and concluded that the prospects for a full-scale commercial system were, under current market conditions, not strong.

On the other hand, it appeared that the possibility of a demonstration-scale plant under the unique conditions in which a public entity might both own the feedstock (municipal solid waste) and use the product (ethanol) was not ruled out. In fact, it seemed wise to pursue such an inquiry into a second round which would sketch the broad outlines of a possible project in technological, operational, environmental and political terms.

The Study Focus

Based on the amount of waste available, the state of planning for integrated solid waste management and the demonstrated interest of public officials in innovative approaches to environmental and energy issues, Economic Research Associates focused on the case for development of an ethanol production facility in or near Lincoln-Lancaster County which would produce fuel for public fleets of buses and cars located in Lincoln.

Engineering Participation

At this second stage of inquiry, it became necessary to pose the study issue to an engineering firm that could provide insight into the general advisability of proceeding further. Economic Research Associates contacted several engineering firms identified by the National Renewable Energy Laboratory as having an interest in development of ethanol from cellulose biomass.

The firm also asked the American Consulting Engineers Council of Nebraska for the names of firms with special expertise in ethanol production from cellulose (they do not list firms by specialty but sent their entire membership list) and consulted the Nebraska Ethanol Board for the names of reputable engineering firms associated with actual ethanol development in Nebraska.

All these sources were supplemented with personal inquiries of individuals known to be familiar with the network of those interested in the concept of ethanol from cellulose. Only one firm surfaced again and again in the process with a strong professional reputation, a portfolio of actual experience and a responsive interest in the project hypothesis. That firm was Raphael Katzen Associates of Cincinnati, Ohio.

The firm has a 50-year history in the production of ethanol from cellulose-containing substances. But, more important, it also responded to inquiries on behalf of the Nebraska Energy Office with full documentation of engagements and publications of principals of the firm. Katzen Associates has consistently expressed interest in the hypothesis of this inquiry and has provided conservative counsel in thinking about any potential project. The firm is currently engaged in Nebraska and makes regular consulting visits to grain-based ethanol installations nearby in Kansas.

An Engineering Hypothesis

Since at least 1983, Katzen Associates has, in written papers and presentations, made the case for a demonstration facility for the conversion of cellulose to ethanol. Based on their success in the pilot stage at a Pennsylvania pulp and paper mill and at a Gulf Oil site in Pittsburgh, Kansas (one ton of feedstock per day), the firm has hypothesized the need for a 50- to 100-ton-per-day to bridge the gap between pilot and full commercial scale operations at up to 2,000 tons per day.

Among the ways that this proposal has been documented are a paper entitled "The Development Rationale for Ethanol from Lignocellulosics," prepared for the Forest Products Research Society in 1983 and another entitled "Bio-Conversion of Cellulosic Wastes" presented to the Forest Products Division of the American Institute of Chemical Engineers at their Biotechnology Session/183 in November, 1991. In the 1983 work, Raphael Katzen, President of the firm, wrote:

> The development of an economically viable enzymatic process to convert cellulose to ethanol involves four major steps. The development starts with bench scale laboratory experimentation and ends with a commercial plant. Between these two steps an information gap exists that must be bridged to allow proper design of a commercial scale plant.
>
> The instruments to bridge this gap are the pilot plant and the demonstration plant. The pilot plant has accomplished the initial scale-up of the process 100 fold. . . This paper will outline the information gathered to date that has allowed the design of the demonstration plant to be completed.

To date that demonstration plant has not been built. Katzen Associates' observations add to the immediate impact that any such facility would have on the Lincoln area by identifying a contribution of national import to both energy, environmental and economic development policy.

This study examines the possbility of pursing the engineers' recommendation for a demonstration plant within the jurisdiction of the City of Lincoln and Lancaster County.

II. Technology

A. An Overview

Technology for the production of ethanol from waste is known and has been piloted.

While trade-offs can be made among the processing variables (preprocessing of feed stocks, for instance, may reduce subsequent production costs but add to the overall costs), no recent breakthrough has dramatically changed the fundamentals of producing ethanol from cellulose.

In simplest terms, the best current method for producing ethanol from cellulose feedstocks involves three major steps:

1. Processing of raw cellulose fiber with acid and heat to separate the sugar molecule chains from lignin.

2. Chemically breaking down the cellulose into sugar with enzymes and simultaneously adding yeast to ferment the sugary liquid.

3. Distillation of the ethanol.

A diagram on the next page illustrates these steps graphically.

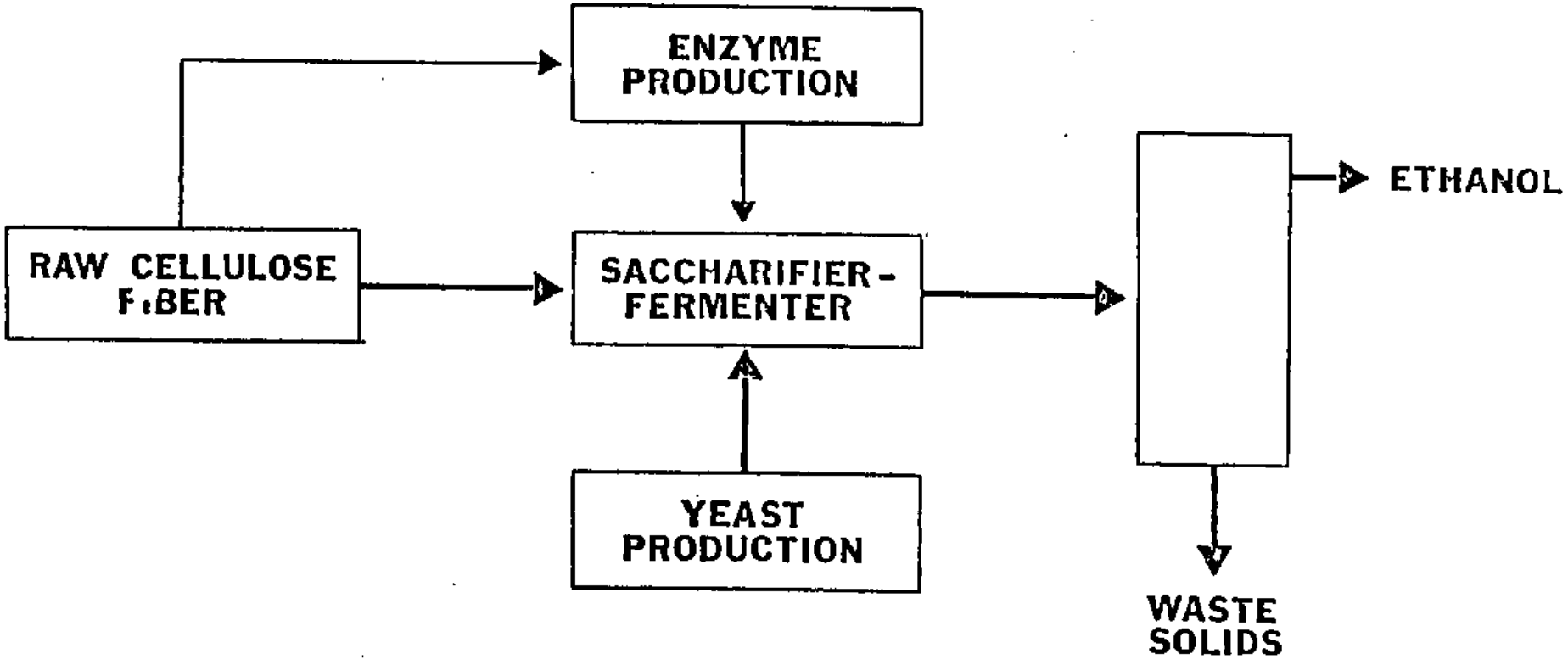
It is important to note that this is a gross simplification which leaves out many meticulous subprocesses, each of which is, in and of itself, a complex chemical problem.

In this phase, Economic Research Associates has not uncovered any other claimants to technological developments which have proved to dramatically alter the best of tried and true approaches to ethanol development.

An Update on Quadrex

Earlier work by Economic Research Associates focused on the claims of Quadrex Corporation, headquartered in Florida, and licenser of a bioengineered microbe which, the company maintains, would radically alter the economics of ethanol production from cellulose. Quadrex has undergone corporate restructuring and restaffing since the completion of previous work in this series.

DIRECT ETHANOL PROCESS



The company has recently been in negotiation with the Clay County Development Corporation of Nebraska and is also said to be considering plant construction in Minnesota.

Quadrex and the Clay County Development Corporation are working on completing an agreement for delivery of ground "biomass residue" to support an as yet unbuilt commercial demonstration plan using Quadrex's proprietary ethanol technology, perhaps the genetically engineered microbe. Plans may also be laid to anchor the plant with conventional corn-based ethanol production, allowing experimentation with biomass and the new technology. At this writing, however, there has been no pilot or demonstration phase of the technology applied to non-laboratory production.

It should be considered, as noted in earlier work, that breakthrough technology, if any, may come from proprietary research and development by a large corporation already in the liquid fuels business. Of this, little can be learned, by design.

The Department of Energy and Large Business

Large players pursuing large-scale commercial research and development in partnership with the Department of Energy include New Energy Company of Indiana and Amoco Oil, both working under Cooperative Research And Development Agreements of the Department of Energy, through the National Renewable Energy Laboratory.

New Energy Company, located in South Bend, Indiana, is the second largest American manufacturer of ethanol, producing 70 million gallons of ethanol per year from dry milling of corn. The National Renewable Energy Laboratory is supporting the development of a pilot plant using corn fiber as a feedstock.

The Amoco project is still in the economic and engineering feasibility stages but is aimed at the conversion of cellulose found in yard and paper wastes to ethanol.

Neither of these projects appears to be aimed at testing radically new technology. Both appear to be of the type which may yield incremental efficiency in well-known, basic methods. There are no indication that these projects contemplate bioengineered microbes or any other "miracle" technology.

B. Expected Inputs

1. Municipal Solid Waste--Lincoln and Lancaster County

How Much Waste Is There?

The Recycling Office of the City of Lincoln reports an estimated 535,000 tons of waste were generated in Lincoln and Lancaster County from July 1992 through June, 1993, the last complete reporting period, and referred to after this as "last year."

This figure includes household and special wastes disposed at the Bluff Road Landfill, the primary metropolitan landfill site; construction and demolition waste; and an estimated 93,000 tons of recycled waste.

Katzen Associates examined the estimates supplied by the City of Lincoln and suggested that about 40% of total waste or approximately 214,000 tons would be "in the classification of lignocellulosic-containing waste," suitable as feedstock for ethanol production.

Of greatest importance in this special portion of all waste is its newsprint, paper, woody, vegetable and food waste content. Katzen Associates suggest that Lincoln-Lancaster may have sufficient solid waste to produce as much as 500 tons of feedstock per day. If used as feedstock, it would supply a "demonstration" class facility and one unprecedented to date.

How Much Waste is Sorted and Recycled?

Of the total of all waste in Lincoln-Lancaster, recycled tonnage comprises about 17%. Because the content of recycled waste differs considerably from the content of all waste, however, it cannot be assumed that 17% of cellulose-containing waste was recycled. Determining with greater precision the amount of potential ethanol feedstock in the waste stream, and what portion of that waste is sorted through recycling, would be a part of the analysis required in subsequent phases of planning a waste-to-ethanol facility.

Table 1 on the next page outlines the source of estimated recyclables for last year.

TABLE 1
CELLULOSE-CONTAINING WASTE REPORTED IN RECYCLING PROGRAMS
July, 1992 through June, 1993

	Estimated cellulosic waste in "Recycling" (in tons)
Private Recyclers (Marketed outside Lancaster County)	26,302
City Participation Programs	
Wood pallet chipping demonstration	Not Available
Wood/brush chipping (See Note 1)	4,599
Christmas trees (See Note 2)	126
Drop-off sites (See Note 3)	2,053

Source: "Summary of Solid Waste Generated and Recycled in Lincoln & Lancaster County, FY 90-91 Through FY 92-93," City of Lincoln, Office of Recycling.

Note 1: Figures for July, 1990 through June, 1991. Production of wood chips from wood and brush after large branches have been removed for firewood and stumps have been removed to form landfill "litter screen."

Note 2: Converted to free mulch for citizens and for grounds use of University of Nebraska and City Park and Recreation Department.

Note 3: Newsprint only. Figures for calendar 1991. Contractor hired to remove.

Prerequisites for Using Waste

These data show there is, in theory, more than enough cellulose waste to provide feedstock for a 50- to 100-ton-per-day demonstration-scale ethanol production facility plant in Lincoln and Lancaster County.

Perhaps of greater concern than the amount of waste is the somewhat unplanned and uncentralized nature of Lincoln-Lancaster's recycling. Though the City of Lincoln designed and enacted what is generally regarded as a very successful conversion from landfilling of yardwaste to home-, business- and institution-based separation (with commercial collection and municipal composting) there is no similar public policy foundation for other recyclables.

Lincoln's recycling programs are largely "educational," "pilot," "demonstration," "voluntary," or "private." None of these is comprehensive or based on a citywide plan. None of these efforts is designed to deal with modifying a wide range of institutional and household behavior. No recycling or collection goals have been set for the region served by Lincoln's landfill.

Importantly, the planning for waste that has occurred since 1992 with the participation of a City of Lincoln/ Lancaster County Solid Waste Management Plan Steering Committee has considered only the costs (sometimes only the price) of efforts without corresponding quantification of benefits.

Scant materials exist to support the recommendations of the Steering Committee which underlie efforts in progress toward Lincoln's "Comprehensive Solid Waste Management Plan." No consideration for use of waste such as that considered in this report is apparent. Without any foundation at all, the Plan points toward an Intermediate Processing Center and Materials Recovery Facility at an unspecified date in the future. (Informal conversation suggests that no such center is envisioned until 1997, at the earliest.)

Alternatives which have proved effective in some other communities such as residential curbside collection of recyclables are dismissed as "not economically feasible," although sufficient economic consideration was clearly not performed.

At this writing, there is no City/County solid waste plan although one is said to be in the draft stages as part of the planning process.

The process does not bode well for consideration of innovative alternatives to traditional thinking--in solid waste management. There is no evidence of the application of economic principles to solid waste planning. There is no discussion of the application of community-or market-based behavioral change incentives or any of a host of promising possibilities being explored in other parts of the United States. It appears to have been driven by extremely limited application of engineering-based concepts rather than by a more appropriate mix of economic, social and public policy-based goals.

2. Municipal Solid Waste--The Region

Without specific financial and economic analysis, nothing can be known about the advisability of drawing municipal waste from surrounding areas.

It is worth noting, however, that there are surrounding communities who have taken responsibility under Nebraska law for disposal of municipal waste. The table below shows estimated amounts in three communities less than one hour by highway from Lincoln.

Waste in the Region (>One Hour from Lincoln)

	Waste/ Tons/Year	Cellulose-Containing Tons/Year	Ethanol Gal/Year
Saline/Crete	6,033	2,413	180,990
Saunders/Wahoo	8,676	3,470	260,280
Seward/Seward-Milford	7,331	2,932	219,930
Total	22,040	8,816	661,200

Source: Based on figures in "Characterization of Municipal Solid Waste in the United States, 1960-2000 (1990 Update)," as reported by SCS Engineers in a study of solid waste in Nebraska, 1992.

While there appears to be more than enough waste collected in Lincoln and Lancaster County to meet the needs of a 50 to 100 ton per day demonstration facility, regional economics, reconsideration of optimal project size and some other unknown factor could make these amounts significant.

In the course of developing the State's solid waste management strategies, consultant SCS Engineers proposed that not only these amounts but an additional 150,000 tons of per year be collected from a region touching Kansas on the south, Iowa on the southeast, metropolitan Omaha on the northeast, Wahoo on the north, and York to the west with Lincoln and Lancaster County as the collection center. Political reaction was swift and negative both in and outside Lancaster County. The plan was never given serious consideration.

C. Expected Outputs

1. Ethanol

Potential Production Range

The range of ethanol output from paper portions of mixed solid waste is about 55-90 gallons per ton of feedstock. Yields vary upward with the cellulose content of the waste stream and are reduced in proportion to the amount of unusable materials which must be separated prior to processing.

A raw wastestream might yield 55 gallons per ton of feedstock. As noted, all the waste that enters Lincoln's landfill could amount to 500 tons per day, producing a conceivable ethanol yield of 27,500 gallons per day or 8.25 million gallons per year.

At the other end of the range, if Lincoln's waste included 100 tons per day of extremely clean waste, say, high quality office paper waste which could be separated out, the yield might be closer to 90 gallons of ethanol per ton. This suggests a total yield of 9,000 gallons per day or 2.7 million gallons per year.

The Katzen Design

Well within this range, but of considerably more merit than the rule-of-thumb calculations above, are the 1983 calculations of Katzen Associates, contained in their work "The Developmental Rationale for Ethanol From Lignocellulosics." This work describes a design for the demonstration-scale facility which has been envisioned as a key link between the laboratory and the marketplace.

In this work, Katzen Associates demonstrate by documentation of their pilot efforts, the unexpected events which can occur by increasing production 100 fold in each aspect of the complex and sensitive process. Having solved these puzzles at the pilot level, however, merely signals the moment to repeat the increase by 50 to 100 fold again to the demonstration level. Again, it is reasonable to anticipate unanticipated consequences.

Still, the firm proposes a demonstration facility capable of processing 50 tons per day of cellulose feedstock. Calculations show ethanol output in the range of 2,360 to 3,750 gallons per day (800,000 to 1,300,000 gallons per year) at this level of input.

Potential Public Use in Lincoln

Special Vehicles--The City of Lincoln currently owns a fleet of buses, four of which use 95% ethanol fuel at a total rate of about 200 gallons per day (about 60,000 gallons of ethanol per year).

In addition, the State of Nebraska operates a fleet of 58 vehicles which can use a mix of up to 85% ethanol. Forty-five of these (76%) are fueled out of Lincoln. These vehicles used 3,675 gallons of mixed fuel in the fleet's first six months of operation. This use required 3,124 gallons or about 6,250 gallons of ethanol annually.

The Regular Fleets--Most of the vehicles owned and operated by the State out of Lincoln use 10% ethanol fuel and consumed a total of 2,425,911 gallons of mixed fuel last year containing about 243,000 gallons of ethanol.

All together, the total current use of ethanol by City buses and State cars is about 311,650 gallons or 40% of the lower range of production estimated from a waste-to-ethanol plant of the size recommended by Katzen Associates.

It should be noted that the City and State do not blend their own fuels but purchase them pre-blended.

Though price alone is an inadequate guide to public decision making in fuels, it should be noted that the City and State currently pay $.90 per gallon for 10% ethanol fuel and $1.31 for 85% ethanol fuel. Price is the primary consideration in public fuel purchasing and, thus, ethanol fuels are viewed as expensive. Ethanol use is avoided unless dictated by public policy or subsidized. Thus, these actual usage figures are for a constrained use of ethanol, not a preferred use, as might be the case if public supplies were produced as a by-product of waste disposal.

What Are the Possibilities?

If that portion of the State fleet of automobiles using 10% ethanol fuel were to be converted to using 85% ethanol, the State's use would change from less than a quarter of a million gallons of ethanol per year to more than two million gallons a year. This figure, while not all in Lincoln-Lancaster begins to approach the productive potential of waste in Lancaster County. Taken together, with all City buses and the conversion of the City and County automobile fleets over time, a match between capacity and use begins to emerge.

Evolving production and use targets could match over time as fleets are replaced and the City's collection and landfill policies mature.

2. By-products

The most significant by-product of ethanol production from solid waste would be a the lignin residue described by Katzen Associates as having "relatively high fuel value." Of course, this residue has value only to an enterprise with a use for it.

The 1992-1996 Biofuels Program Plan of the National Renewable Energy Laboratory, affiliated with the U.S. Department of Energy, observes that the lignin by-product "can be converted to high-value chemicals. In the near term, the most cost-effective use for lignin will be as a fuel to power the biomass-to-ethanol process."

Katzen Associates, however, somewhat more familiar with real-world applications through their work at the pilot stage suggested in a 1983 paper:

> In order to reduce the cost of the demonstration plant it would be desirable to locate it adjacent to a parent facility, which could supply steam, water, power and facilities for disposal of liquid and solid wastes. These services could be purchased from the parent facility, which would be much less expensive than building a stand-alone demonstration plant with all of the above capabilities for the proposed length of operation of the plant (2 1/2 years).

Familiar as the firm is with Nebraska's low-cost public power, however, Katzen Associates note, "Alternatively, if the facility would be located adjacent to an existing public utility, the fuel could go to that facility, with steam, electric power and water being purchased from the power facility for ethanol plant operation."

Cost and benefit of these two alternative uses of the lignin by-product would be a part of any subsequent full-scale feasibility study and would have significant implication for siting.

3. Range of Appropriate Methods

Based on what is known, Katzen Associates suggest acid pretreatment and enzymatic hydrolysis for this project.

4. Availability of Design

Without doubt, there is no standard facility for the production of ethyl alcohol from municipal solid waste. The best guide is the technically successful pilot plant (no longer operating) developed by the private sector at Pittsburgh, Kansas.

It must be understood that ethanol-from-waste is experimental at the demonstration stage and any ethanol plant will be a customized, site-specific application with many unknowns.

5. Availability of Equipment

Because relatively conservative technical methods are recommended, individual pieces of equipment are developed and well-known. Yet, it is the nature of engineering "scale ups" that the piecing together of the vats, boilers, steam pipes and storage tanks is in large part experimental. Every scaling up--100 fold from bench to pilot, another 100 fold from pilot to demonstration, and another 10 fold or more to large-scale commercial production--is guaranteed to present unanticipated design problems which must be solved. Such uncertainties are part of the business of development and must be recognized in the planning and financing of systems.

Katzen Associates, for instance, in estimating the capital costs of a 50-ton-per-day demonstration plant included not only a 10% contingency, as is customary in construction projects, but about 20% next to the bottom line for "estimated potential modifications."

Even at the commercial level, plants are hardly turn-key designs. They are still custom engineered to the feedstock, site, transportation and economic variables of the individual installation.

6. Range of Sites

In any consideration of site, the relatively high value of the primary product, ethanol, and its portability as an energy-dense liquid reduce the importance of location based on output. This is especially true if the primary use of the ethanol produced is a public bus and auto fleet located in Lincoln.

Feedstock, however, is at least one element significant in siting. A major cost in solid waste disposal is transportation. Each loading, unloading and transferring of waste materials adds cost to a commodity that has a negative, neutral or, at best a low positive value. Therefore, it is reasonable to consider siting at or near the location for collection of cellulose-containing wastes. Recycling options adopted by the City of Lincoln will be important in determining the range of sites. Conversely, a decision to participate in an ethanol plant as an alternative to exporting waste paper or landfilling other waste, could help shape community solid waste management planning.

The additional environmental impact, if any, of the production process on any site already pressed into disposal use will require careful specification and would be part of the overall benefit/cost calculation of the project.

D. Technology Summary

1. Two public policy goals coincide to support further investigation of the feasibility of a demonstration-scale plant for the conversion of municipal solid waste to ethanol in Lincoln and Lancaster County. They are:

a. The City of Lincoln "owns" a large quantity of municipal solid waste for which it is responsible. It also operates a fleet of cars and buses and is the site for a large part of the fleet of vehicles of the State of Nebraska.

The City is now in the process of considering how it will deal with the waste for which it is responsible. It should consider the inclusion of a waste-to-ethanol demonstration plant in its Solid Waste Management Plan as an alternative to burial or sale on the recyclables market.

b. Throughout the United States, progress toward full-scale production of waste-to-ethanol has stalled at the pilot stage. Construction of a carefully designed demonstration plant in Lincoln could contribute significantly to national energy policy.

2. In considering such an effort, however, it must be understood that ethanol-from-waste is experimental at the demonstration stage and any ethanol plant will be a customized, site-specific application with many unknowns.

3. It appears that there is more than enough cellulose waste to provide feedstock for a 50- to 100-ton-per-day demonstration-scale ethanol production facility in Lincoln and Lancaster County.

4. Collection, of cellulose-containing wastes, however, is problematic. At present, there is no comprehensive policy on collection of recyclable waste in Lincoln. The direction the City takes in solid waste planning will be important to the consideration of a demonstration-size ethanol production facility in Lincoln/Lancaster County. The City is in a position to build upon the success it experienced in changing the behavior of the community following a landfill ban on yardwaste.

5. Taken all together, the total current use of ethanol by City buses and State cars is about 311,650 gallons, about 40% of the lower range of production estimated from a waste-to-ethanol demonstration plant. These figures, however, represent constrained use during a time when ethanol is considered an expensive fuel by those who buy for and operate public fleets. Because of price, there is currently a detectable bias against use of ethanol among those who deal with it every day in public fleet management.

6. If public entities in Nebraska were to make a firm, sustained choice to maintain and increase the use of renewable fuels in all buses and to continue the conversion of automobile fleets to a higher proportion of ethanol use, over time, a match between production and usage at the demonstration size emerges. Such evolving production and use targets could be matched over time as governmental fleets are replaced and the City's collection and landfill policies mature.

7. Because the economic feasibility of the proposal explored in this study rests on the City's and State's continued and increased use of ethanol fuels in their own fleets is important. Thus, the choices made by those who make public policy and those who specify and operate public vehicle fleets is important.

8. By rule of thumb, the range of capital costs for a waste-to-ethanol plant in Lincoln ranges from $11 to $33 million. Engineering estimates made in 1983 of a specific demonstration-size facility placed the cost then at $22.6 million. This range should be regarded as establishing a ballpark only.

III. Operations

A. Sources of Funding

Sources of operational funding should come from the project, provided full costing of benefits is included in the feasibility calculation. If the benefits of the facility do not exceed the costs, there can be no justification for proceeding.

Project plans should differ from most, however, in an insistence on full costing. As has been noted above, the City's prior examination of yardwaste recycling included only costs without any complementary calculation of benefits. Throughout the process of public information connected with the City's planning process for disposal of yardwaste only cost information was provided to the public and City decision makers.

In traditional engineering, economics beyond the project itself are referred to as "externalities," and set aside as irrelevant to the project. Such terminology is out-of-date as the growing body of regulatory requirements pushes costs once "external" to production back into the operational equation. It has always been out of place in calculation of public projects where the highest and first purpose of all endeavors is the shared public good which usually lies "external" to every specific project.

Some efforts to quantify "externalities" may be occurring in the public sector with relevant application to this project. But, just as a specific engineering approach is required to look at the specifics of a project, so should a specific "resource economist" be part of the full feasibility team to work in concert with engineering, to provide step-by-step micro- and macro-economic feedback on project variables as they come under consideration.

At a minimum, operational funding sources should include on-going credits for the offset costs of land disposal of any waste used for feedstock, with periodic review of prices of transportation, environmental protection and other changing variables.

All calculations should be on a life-cycle basis which includes both positive and negative effects of project expenditures.

In the best of all possible worlds, these items would have been included in calculations of landfill fees. That, however, has not usually been the case. In fact, one of the benefits of further study of the feasibility of a waste-to-ethanol facility for the City of Lincoln should be the inclusion of methods for such full cost analysis for other uses by the City.

As to the case at hand, only a full feasibility study with a specific design and site can render specifics on operational funding. Economic Research Associates recommends that development of full-costing concepts, with special attention to public sector economics, should be a selection criterion for any professionals engaged to move this project ahead.

A Foreshadow of the Importance of "Externalities"

Among the discoveries that has driven Katzen Associates' interest in further development, particularly using municipal solid waste as a feedstock, is the positive impact of public financing on the final economic outcome of a larger scale project. While low interest rates, constraints on once wide-open public financing and investors' tax rates have altered the importance of this factor, indicators showing interest rates are on the rise again, may reinvigorate the importance of public finance.

In a 1982 paper entitled "Economics of a Combined Resource Recovery Cellulose Alcohol Plant," (Wood and Agricultural Residues, 1983, pp. 303-313) comparing total equity financing with a mixed debt and equity strategy, Katzen Associates concluded:

> In summary, it can be said that the method of financing has a great impact on the profitability of the combined resource recovery-cellulose alcohol facility. The need for such a facility certainly is obvious. **To significantly alleviate a major national waste problem alone should be enough to justify a municipality's involvement through bond financing.** (emphasis added) Producing a valuable liquid fuel octane enhancer from what now goes to landfill or is burned is added incentive to use the cellulose to ethanol technology.

B. Product Distribution

The Closed Loop

The jargon "closed loop" system was used in an earlier phase of consideration without specific definition. As used here, it implies a production system in which the producer is also the prime user of the product.

A closed loop system is often reasonable as a microeconomic system when the producer has a special obligation for the disposal of a substance which, if not further processed, represents an additional production cost. Two such cases illustrate this concept.

A Private Sector Example

In the private sector, mills which process wood pulp to make paper also produce a residue by-product. A company has several choices in dealing with this residue. At some times in the past, just disposing of the residue as waste has been economically efficient for the producer because it successfully "externalized" the cost of disposal from the producer to the public.

At other times, when market conditions have shifted, the fuel value of the residue has become great enough for the mill operators to consider using it in a closed loop system to produce power for the paper-producing process. In this case, a closed loop system suggests itself, primarily to reduce the costs of production.

In recent times, the imposition of regulations have had the effect of forcing the "internalization" of the costs of dealing with residues back on the producer. In this case, a closed loop system suggests itself at any time when the combined positive cost reduction benefits of using a residue combine with avoidance of the costs of special handling which would be required to simply dispose of a residue. In such a case, a part of the microeconomics, even in the private sector, is the presence of an additional negative cost.

A Public Sector Example

A closed loop system suggests itself in the case at hand because the special microeconomics of public policy are at work in addition to the ordinary production economics described in the private sector example above.

The City of Lincoln finds itself in the unique position of:

- --"owning" collected wastes that represent a municipal cost if merely dumped.
- --owning a fleet of vehicles that carry an operating cost.
- --potentially able to benefit from accepting the development risk of creating a closed loop system.
- --potentially able to benefit from transfer of the system to the private sector when the costs of high-risk development have been recovered.

Some Guides for Ownership

Economic Research Associates suggests that any policy which holds that private ownership is always superior to public enterprise is inadequate. If this were so, there would be no purpose for government. Even Adam Smith, the imputed theoretical father of the American free enterprise system wrote extensively of the role of public investment to support private enterprise.

Rather, policy makers should apply the differing economic characteristics of the public and private sectors to the risk factors at work in various enterprises.

Without question, the development of a demonstration size waste-to-ethanol facility is a venture that fails under purely private economics with current market conditions. At least in theory, if there were profits to be made, such a project would attract the capital needed for start-up. Economic Research Associates can attest to the number of sharp thinkers in search of just such a breakthrough because the research for this work has required finding and talking to them.

But, in every case examined, even with tax and other developmental incentives figured in, such projects are so weak as purely private ventures that none have taken root.

Research and development is, however, a reasonable role for the public sector when 1) it is uniquely positioned to benefit directly and 2) the potential for private ownership after initial risk is reasonable.

C. Project Economics

Beyond the project-specific microeconomic analysis discussed in "Sources of Funding" above, full quantification of the impact of the project on community economics should occur.

This macroanalysis should include the direct and indirect effects of the project on the economies in which it operates, including the effect of planning and construction expenditures and on-going operations. The economic impact should include at least:

1. Sales Output--calculation of the full effects of all direct and indirect purchases related to the project.

2. Wages and Salaries--calculation of all the direct and indirect wages and salaries due to the project.

3. Jobs--calculation of all direct and indirect employment due to the project.

4. Value Added--calculation of the impact on the Gross State Product.

5. Fiscal--calculation of the impact on the public sector (taxes and fees, for instance).

All calculations must include "substitution" effects, meaning they should be the net difference between expenditures within the defined economy and expenditures outside the economy.

Only with this type of economic analysis can true trade-offs between the costs of business-as-usual and alternatives be determined. This approach should underlie not only the feasibility economics of this project but all trade-off decisions related to solid waste management and alternative energy investments.

D. Start-up Costs

The rule of thumb for estimating capital costs of an ethanol-from-cellulose facility is $4 per annual gallon (for a 10 million-gallon plant, $4 X 10 million = $40 million).

Based on earlier rough estimates, the range of capital costs for a waste-to-ethanol plant in Lincoln ranges from $11 to $33 million. Katzen Associates estimated the costs of a 50-ton-per-day demonstration facility at $22.6 million in 1983. This range should be regarded as establishing a ballpark only, and is probably low because the effect of fixed start-up costs cannot be fully reflected in a rule of thumb.

By comparison, the rule of thumb for ethanol-from-grain plants is $2 per annual gallon, although, actual cost figures can drop below $1 and rise to $4 depending on site factors.

It may be necessary or advisable to inject funds into the project for start-up. These should be recognized and amortized into the lifetime operations of the project so that lifetime costs and benefits can be known and planned for.

E. Cost of Production

Without a full feasibility study--the next step after this report--nothing specific can be said about costs. The principles for calculation, however, outlined above should apply to production cost calculations.

F. Sources of Cash Flow

The project should stand on its own after a reasonable period of start-up which can only be specified in project feasibility and after full calculation of community benefits. All cash into the project should be calculated against alternatives, including purchasing ethanol fuels on the market, to prove quantitatively that the community is deriving benefits which exceed the community's full costs.

G. Operations Summary

1. Operation of a demonstration-size waste-to-ethanol plant may be economically positive under the special conditions that exist when the producer has a special obligation for the disposal of a substance which, if not further processed, represents an additional production cost.

2. Analysis requires much more than incomplete and price-driven calculations which all too often represent the state of the art in benefit/cost assessment of public projects. Only a full feasibility study with a specific designs and sites can return the specifics on operational funding under these conditions. Development of full-costing concepts, with special attention to public sector economics, must be a part of any decision to move ahead with further analysis. Qualifications on this basis should be a selection criterion for any professionals engaged to move this project ahead.

3. The economic analysis of a demonstration-size waste-to-ethanol facility should include the direct and indirect effects of the project on the economies in which it operates, including the effect of planning and construction expenditures and on-going operations. The economic impact should include at least:

1. Sales Output--calculation of the full effects of all direct and indirect purchases related to the project.

2. Wages and Salaries--calculation of all the direct and indirect wages and salaries due to the project.

3. Jobs--calculation of all direct and indirect employment due to the project.

4. Value Added--calculation of the impact on the Gross State Product.

5. Fiscal--calculation of the impact on the public sector (taxes and fees, for instance).

All calculations must include "substitution" effects, meaning they should be the net difference between expenditures within the defined economy and expenditures outside the economy.

4. Such full costing analysis between the costs of business-as-usual and alternatives should underlie not only the feasibility of this project but all trade-off decisions related to solid waste management and alternative energy investments.

5. Project design should include at least an examination of the beneficial effects of transferring ownership from the public to the private sector after operations become stabilized. In this case, the cost of demonstrating the technology supports a research and development role for the public sector because public entities are uniquely positioned to benefit from the plant outputs, reducing the high cost.

After the period of high initial risk, however, a greater good may be served in the community by selling the facility to private ownership. This secondary goal, however, should be planned from inception for best overall economic results.

IV. Environment

Environmental impacts need only be separated from all other considerations of a project when improperly omitted from design. In large part the effects which have given environmental redressment and regulation its nightmarish reputation have been uncertainty of regulatory requirements throughout the life of the project. Situations in which environmental regulations have been imposed on existing operations have been known to double plant costs and operations. But as the age of environmental regulation matures, integration of constraints into basic design and designing for flexibility have become hallmarks of good design.

Most troublesome have been those facilities designed in an era when the design solution to troublesome effects of production was to "externalize" the costs by dumping them into the public domain in the hope of avoiding imposition of cost on production. The cost of redressing bad design has come to be recognized by many entities now as far more expensive and disruptive than building to reduce the effects on the environment.

This project should be built with the costs of environmental protection fully integrated as a "cost of doing business."

A. Areas for Attention

In both design and operations the general areas of concern related to production of ethanol from municipal solid waste would include at least:

1. **Site Preparation.** Any construction which involves the devegetation of at least five acres must receive a permit to ensure that "best management practices" have been planned for erosion control of the newly bare soil.

   Regulations in this area are long-standing and appear stable.

   Insofar as any facility would come under the purview of solid waste management, more stringent geohydrologic characterization and protection may be required. Solid waste processing also requires special restrictions on wetlands construction, airport proximity and earthquake resistance (Lincoln is in an earthquake zone).

   This is an area of new, untried and evolving regulation without long-term stability and might require considerable negotiation with regulators.

2. **Feedstock Processing.** The ordinary concerns that any landfill operation must consider include noise, dust, litter, control of disease-bearing creatures and odor. In addition, if long-term storage of feedstock were anticipated, discharge of organic compounds, such as methane could lead to potential air quality or explosive gas problems.

Solid waste regulations related to operations may require special record keeping, training and notification but, in this area are relatively long-standing and stable.

3. **Boiler Operation.** Air quality standards apply to the burning of fuels, whether relatively clean natural gas, coal or ethanol residue.

Regulations in this area are long-standing and appear stable.

4. **Cooling Water.** In the process of producing ethanol it is necessary to include a system for removing heat, usually through water-carrying pipes. The temperature and acidity of any water that might be discharged from those pipes is of concern related to operations.

Periodically, such pipes might need to be chemically "descaled" and the chemical content of water discharged after that process is also a matter of regulatory concern.

Regulations in this area are enforced through permitting. They are long-standing and appear stable.

5. **Distillation.** Air quality standards for volatile organic compounds, (regulators will call these "VOC's") created in the process of distillation, including aldehydes and ethanol itself, pertain.

Regulations in this area are long-standing and appear stable.

6. **Liquid Discharge from Processing.** Any water that leaves the processing system itself must meet certain standards for "biochemical oxygen demands," (regulators will refer to these as "BOD's"), a measure of the impact that discharge will have on dissolved oxygen in the body of water into which the discharge is made.

Water must also meet standards for "suspended solid particles," that is materials from the processing that remain in the discharge and which would be emptied into a body of water.

Finally, there would be concerns about contaminants in the water as a by-product of the process. These might include ammonia or metals. Because of the nature of the feedstock, the scope and interest in contaminants could be expected to be more intense under newly developed solid waste rules and regulations.

If meeting regulatory standards requires special after treatment, there is a special permit process for the treatment system. In some cases, facilities can share municipal water treatment facilities, but this too requires some special attention and permitting.

Regulations in this area are enforced through permitting. They are long-standing and appear stable.

7. **Storage and transfer.** Air quality standards for volatile organic compounds apply in both storage and transfer.

A "storm water permit" may be required in connection with storage of feedstocks and other substances, to ensure that there is no adverse impact from contaminated rain or snow-melt run-off.

Regulations in this area are enforced through permitting. They are long-standing and appear stable.

8. **Residue Incineration.** If a design were to include incineration as a means of disposing of process residue, rather than burning within the plant or at a nearby co-generator, this would be an area of considerable attention.

This is an area currently under reconsideration and revision. Regulations on both air discharge and ash disposal may undergo change, increasing the risk and cost of this method of disposal.

B. Impact on Existing City Operations

The tradeoffs between the impact of landfilling and ethanol generation lie at the very heart of this project. The cost in design and maintenance of any new way of handling waste, whether focused on centralized mechanical sorting, which many engineering firms seem to favor, or changing human behavior, which has worked well in some areas and failed in others will have an impact on existing city operations. But so will making no change.

If the community continues to grow, if environmental standards continue or increase, if there is no change in the amount of material that comes into the community to be used and ultimately disposed, there will be an impact of continued landfilling.

Economic Research Associates suggests that the impact be considered in more than financial terms. In addition, there will be an impact on the shape of the city if more intense processing of waste occurs on or near the landfill site or in a new location. There will be a strong impact on the City socially if businesses and individuals are asked or required to participate in sorting of waste, prior to pick-up.

Ultimately, however, the impact on the City is driven, not by an ethanol project, but by the forces of commerce which bring materials into the City's jurisdiction. Ethanol production should be seen as just one of the many pieces of the puzzle of disposition of materials imported into the area as a part of ordinary commerce.

C. Environmental Summary

1. This project should be built with the costs of environmental protection fully integrated as a "cost of doing business." Rather than incurring the cost of evasion and avoidance, the plant should integrate the known environmental standards and, to the greatest extent possible, leave flexibility for the changing demands of the future.

2. Known environmental standards exist in the following areas of likely concern to plant designers:

a. Site preparation
b. Feedstock processing
c. Boiler operation
d. Cooling water systems
e. Distillation
f. Liquid discharge from processing
g. Storage and transfer
h. Residue incineration

3. If Lincoln continues to grow, if environmental standards continue or increase, if there is no change in the amount of material that comes into the community to be used and ultimately disposed, there will be an impact of continued landfilling.

In addition, there will be an impact on the shape of the city if more intense processing of waste occurs on or near the landfill site or in a new location. There will be a strong impact on the City socially if businesses and individuals are asked or required to participate in sorting of waste, prior to pick-up.

4. Ultimately, the impact on the City is driven, not by an ethanol project, but by the forces of commerce which bring materials into the City's jurisdiction. Though it is typical that only the variable costs of a new proposal such as the ethanol production envisioned in this study are considered--and often rejected--this project should be seen as just one of the many pieces of the puzzle of disposition of materials imported into the area as a part of ordinary commerce.

V. Politics

"Politics," in this case, means presenting the results of further study to City management, at least the Mayor and City staff, and to potential public investors.

In both the private and the public sector, such a plan should be well thought out. It should anticipate and meet the concerns of management. It should be complementary to existing organizational goals and plans, whether the organization is a city or a business.

All too often, ideas come forward to management--private or public--on the basis of technical strength alone (usually a very small part of the entire operation) or policy values alone (even proponents have been heard to testify that environmental projects aren't efficient--they're just the right thing to do). In both cases, only part of the planning job is done. Thus, some of the most important parts of the "politics" of the project have already been described. If the project doesn't make sense, it ought not to go ahead. But it ought not to be squelched just because the full efficiencies were not calculated, as is common in such projects.

Beyond that, there is the human element of politics. Is there an automatic predisposition against the project? If not now, will it emerge? And from where is it likely to come?

A. Assessment of the Political Climate for Participation of the City of Lincoln

The Mayor

Lincoln boasts a popular mayor in Mike Johanns and an approachable one. A visit to his office to outline the project very briefly was cordial. He invited Economic Research Associates to call on the City's departments with questions and reactions. In return, Economic Research Associates promised the Mayor a conservative business-like approach to the work.

The Mayor appears to be a moderate risk-taker, tuned in to the perceptions of citizens. Trained as an attorney, he appears to rely on the advice of experts and does not rush to judgment. He developed the reputation as something of a healer or mediator before his days as a public official and appears to have carried that characteristic forward in his administration. Mayor Johanns does not fight or scapegoat the City Council though he is not averse to differing with them.

The City Council

The Lincoln City Council is committed to working its differences out early on and informally, but usually not in formal public sessions.

It is not the style of the present Council for one member to spring an idea on others. Thus, new projects are introduced slowly, mulled over and may be modified many times before they come to public attention.

Yet, as with most legislative bodies, projects need a champion. One City Council member has had a longer standing interest and a strong record not only in promoting but in bringing to fruition seemingly impossible energy and environmental feats. That is Councilman Curt Donaldson, who was active as a citizen in establishing the City's policy on separating yardwaste from other waste. Recently, he was successful in turning the attention of the Lincoln Public Schools away from conservative school heating technology to efficient ground-based heat exchangers. Councilman Donaldson retains his interest in innovative treatment of waste--he is wondering whether methane can be retrieved from the City's compost operations, for instance--and has previously considered other ethanol production plans.

Councilman Donaldson had hoped to talk in more detail with Katzen Associates about a possible Lincoln ethanol facility but, at the last minute, was not able to make the trip. He can be counted on for counsel in developing this project. His support would be critical.

The Case for Lincoln

Katzen Associates suggest that it is time to go beyond pilot-level projects in order to make progress in converting municipal solid waste into ethanol. They are convinced that they have developed design and installation technology beyond piloting.

Lincoln is the right size for such a demonstration size project and the interactions between City-County and State government are frequent, long-standing and generally positive.

Lincoln is on the verge of taking additional steps toward completion of a comprehensive solid waste management plan. This is the right stage to plan complementarily for the diversion of recyclable materials from the City landfill.

B. Assessment of Potential Public Partners

The State of Nebraska

The pro-ethanol administration of Governor Ben Nelson has already signaled its interest in this project through Energy Director Bob Harris who has funded two rounds of feasibility--one to see what type of waste-to-ethanol facility might work anywhere in Nebraska and this present study to describe in broad terms how a demonstration-scale, closed loop facility might come on line.

Lincoln-Lancaster

Nebraska's two largest ethanol-fueled fleets are sited in Lincoln, one owned by the City, and other by the State, making these two entities likely partners in any further ventures.

Federal Agencies

The activist policy mandates of the Clinton administration to get out of the lab and into the economy should make the project attractive to potential federal funders--perhaps in the Department of Energy or its laboratories, in the Environmental Protection Agency or the Department of Agriculture, for instance--some of whom appear anxious to move beyond mere theoretical speculations about waste-to-ethanol technology.

Public Power

As already noted, a power-producing utility could be partner in the use of plant by-products. In Nebraska, that would be a public partner.

C. Range of Methods of Ownership and Operations

Under the dictates of the Clinton administration to "reinvent government," every opportunity should be exercised to consider new ways of funding a facility in the public interest.

The patterns of private sector financing should be considered for possible adaptation of such models as "venture" investing and other means of funding high-risk ventures.

Whereas conventional private sector venture capital would pass over such a project in search of high and rapid returns, the public sector can be more patient. Economic Research Associates has long maintained that part of the new forms of government should be an end to granting in favor of investing and underwriting with the possibility of writing off sour investments at the end, rather than granting at the beginning.

Although capital costs remain an unknown, there may be sufficient reserves throughout federal programs for considerable financing (large amounts have been made available for ethanol production from dedicated crops, a far less efficient alternative in many regards than reuse of the daily municipal waste "crop").

It is likely that financial innovation can come more easily from small instigators like the Nebraska Energy Office than from federal agencies. Witness the history of the Nebraska Energy Office's "revolving municipal grant" programs for funding city conservation equipment and the success of its bank-based conservation lending program. The Nebraska Energy Office should give strong consideration to exploring funding mechanisms which pilot truer public investment than mere appropriations and grants, at its own initiation, even if not suggested or required by funders.

Development in the Private Sector

In keeping with a public investment approach, the Nebraska Energy Office may wish to position itself as a patient broker, scanning for a time in the future when, after project risk has been paid off, a stable ethanol production facility could be sold or leased to the private sector.

This would replicate the role of the private sector developer who pioneers at high risk for high return with the goal of turning mature property over as soon as possible. In the opinion of Economic Research Associates, it is a proper developmental role for government and more so if it is carefully planned from the beginning as a demonstration only.

All too often, the phrase "public/private partnership" is cheapened and wrongly substituted for "donor." In a partnership, there is an exchange of value between parties and an expectation that in the process of the venture each party will move toward its goals, whether profit or public purpose. That should be the standard under which any partnerships attach to this project.

D. Political Summary

1. "Politics," in this case, is defined as presenting the case for a full feasibility study to City management, at least the Mayor and City staff, and to the City Council, as potential public investors and beneficiaries.

2. Such a plan should be well thought out. It should anticipate and meet the concerns of management. It should be complementary to existing goals and plans, of the City. And, without question, it will have to include supportive funding.

All too often, ideas come forward to City policy makers on the basis of technical strength or policy values alone. In both cases, only part of the planning job is done.

3. Because the day-to-day managers of most public entities, as opposed to elected officials, feel they are under stress merely to meet the already defined needs of the day, new and different ideas, regardless of merit, are generally greeted with concern. Sooner or later, these managers are likely to react negatively, in private, if not in public, to any proposal like the one in this study. This is only one of many meritorious proposals for change that many long-time City managers have seen come and go. In the experience of Economic Research Associates, most die from skepticism and apathy, not outright opposition.

4. There has been no instant opposition to considering the possibility of a waste-to-ethanol facility in Lincoln. On the other hand, little excitement has been revealed. The Nebraska Energy Office must examine its commitment to this project and should expect to make a focused, concerted effort over many months if it wishes to make this contribution to renewable fuels development in the United States.

VI. The Next Step

1. The Nebraska Energy Office should consider whether it wishes to focus on this project of sufficient merit to dedicate itself to being the primary engine behind its accomplishment. The Energy Office should expect to take upon itself the role of chief financial broker and participant for the project if it wishes to see progress.

2. The next step is a full feasibility study. Economic Research Associates recommends a contract which provides for a team of both engineering and economic analysis experts working as one at every stage of the study.

3. The study should produce site-specific recommendations based on examination of all reasonable alternatives for meeting project goals. The study would specify at least construction, operational and marketing variables which meet the project constraints outlined in this study.

4. The Energy Office should draw up a special list of potential bidders on any such feasibility study which requires demonstrated competence:

- --in full costing of public sector economics as specified in this study
- --in actual participation in the design, construction and operation of waste-to-ethanol technologies.

APPENDIX

RKAII CONSULTING ENGINEERS

RAPHAEL KATZEN ASSOCIATES INTERNATIONAL, INC.
2300 WALL STREET SUITE K, CINCINNATI, OHIO 45212

January 21, 1994

Ms. Kandra Hahn
Economic Research Associates
Barr Terrace, 1044 H Street
Lincoln, Nebraska 68508

Re: WH 003
Municipal Waste Demonstration Facility

Dear Ms. Hahn:

Your visit to our office on January 12 was most beneficial. It enabled us to obtain an idea of your proposed project for processing municipal waste in the Lincoln/Lancaster County area, involving production of motor fuel grade ethanol and other by-products.

From the data you left with us, it appears that your area has more than one-half million tons per year of total waste, of which approximately 40% would be in the classification of lignocellulose-containing wastes. Although there is some separation and recycling at present, this amounts to only a small percentage of the total waste material. Of greatest interest for ethanol production would be waste containing newsprint, other paper, woody and vegetable wastes, and some parts of food waste, all of which have a substantial lignocellulose content. Such wastes could amount to the order of 500 tons per day.

Since there is, at present, no central municipal solid waste (MSW) sorting facility, we recommend that a simple facility of this type be included in a proposed commercial demonstration program. This would take anywhere from 100 to 500 tons per day of waste, separating heavy materials, such as metals, glass, heavy construction materials, etc. from the lighter fraction containing lignocellulosics and plastics.

This light stream would be the feedstock for a proposed facility for conversion by acid pretreatment and enzymatic hydrolysis of cellulosics to sugars and, with appropriate fermentation organisms, to motor fuel grade ethanol. Residue from the process would be of relatively high fuel value, and could be pressed for use as fuel to produce steam and power for the facility. Alternatively, if the facility would be located

adjacent to an existing public utility, the fuel could go to that facility, with steam, electric power and water being purchased from the power facility for ethanol plant operation.

Based on our experience with two pilot plants; namely, Gulf Oil Chemicals at Pittsburg, Kansas, which processed a wide variety of materials, including MSW, agricultural residues, forest residues, and pulp and paper mill waste; and a later pilot facility at Procter & Gamble's Mehoopany, Pennsylvania pulp and paper mill, processing waste from that mill, we believe that we have a strong technology base and experience to be utilized for the design of a proposed commercial demonstration facility in Lincoln/Lancaster County.

Furthermore, during the past two years we have had the opportunity to utilize this technical knowledge and data in engineering studies for commercial facilities to produce motor fuel grade ethanol from MSW, pulp and paper mill waste, and an agricultural residue.

On the basis of this experience, which we believe to be the most advanced and comprehensive available for this particular technology, we would be pleased to work with you and your associates in first evaluating, and then proceeding with, a commercial/demonstration facility to process municipal waste in Lincoln/Lancaster County. As a first step, we would propose a site-specific feasibility study, for which we would provide the technology base, and development of investment and operating cost factors; while your organization would provide feedstock acquisition strategy along with the economic evaluation, including governmental aspects of waste disposal and their effect on economics of the operation.

If the feasibility study indicates a reasonable economic and social benefit for such a facility, we would be pleased to provide our proposal for design of such a facility, to be executed in cooperation with local engineers and constructors, to complete engineering, construction and start-up operations of the facility. We would also be pleased to provide Operations Management Services to aid in ongoing improvement of operation of the facility.

Should this proposed program be acceptable to your group and the local authorities, we would be pleased to provide our proposal for carrying out the site-specific feasibility study as the first phase of the program, in conjunction with your organization.

It was a great pleasure to have the opportunity to discuss your interesting approach to the local waste disposal problem. We look forward to the opportunity of working with you toward a solution.

Sincerely yours,

Raphael Katzen

Raphael Katzen
Chairman

RK:aw

LIST OF WORKS CONSULTED

Barrier, J.W., M.R. Moore and G.E. Farina. "Ethanol from Cellulosic Agricultural Feedstocks," presentation to the Alcohol Fuels Semiannual Contractors Review Meeting, Muscle Shoals, AL: Tennessee Valley Authority, Office of Agricultural and Chemical Development, Biomass Branch, July, 1986.

Barrier, J.W., R.O. Lambert and J.D. Broder. "Ethanol and Coproducts from Biomass," presentation to the Italian Biomass Association, Verona Exposition on Agriculture and Agricultural Devices, March, 1988. Muscle Shoals, AL: Tennessee Valley Authority, Office of Agricultural and Chemical Development, Biomass Branch.

Barrier, J.W., R.O. Lambert and M.M. Bulls. "Potential Contribution of Furfural to the Economics of Ethanol Production From Hardwoods," presentation to the Southern Biomass Conference. Muscle Shoals, AL: Tennessee Valley Authority, Office of Agricultural and Chemical Development, Biomass Branch, September, 1989.

Barrier, J.W., M.M. Bulls and J.D. Broder and R.O. Lambert. "Production of Ethanol and Coproducts from MSW-Derived Cellulosics Using Dilute Sulfuric Acid Hydrolysis," a presentation to the Twelfth Symposium on Biotechnology for Fuels and Chemicals, Gatlinburg, TN. Muscle Shoals, AL: Tennessee Valley Authority, May, 1990.

Barrier, J.W., M.M. Bulls and T.M. Shipley. "Ethanol Production from Refuse-Derived Waste Using Dilute Sulfuric Acid Hydrolysis," a presentation to the National Bioenergy Conference. Muscle Shoals, AL: Tennessee Valley Authority, March, 1991.

Barrier, J.W. and M.M. Bulls. "Feedstock Availability of Biomass and Wastes," a included in the ACS Symposium Book Series, Emerging Materials and Chemicals form Biomass. Muscle Shoals, AL: Tennessee Valley Authority, National Fertilizer and Environmental Research Center, Biotechnical Research Department, March, 1991.

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

Bergeron, P.W., C.J. Riley. "Wastepaper as a Feedstock for Ethanol Production." Golden, CO: National Renewable Energy Laboratory, November, 1991.

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.

Biomass Research Program Update, National Fertilizer and Environmental Research Center. Muscle Shoals, AL: Tennessee Valley Authority, October, 1990 and May, 1991 editions.

Broder, Jacqueline D. and John W. Barrier. "A Case for Biomass Utilization," presentation prepared for the Symposium on Energy Futures, Kiawah Island, SC. Muscle Shoals, AL: Tennessee Valley Authority, May, 1991.

Bulls, M.M., T.M. Shipley, J.W. Barrier, R.O. Lambert and J.D. Broder. "Comparison of MSW Utilization Technologies-Ethanol Production, RDF Combustion, and Mass Burning," a presentation to the Southern Biomass Conference. Muscle Shoals, AL: Tennessee Valley Authority, January, 1991.

Conway, Roger K. "USDA's Biofuels Program," Energy Crops Forum. Oak Ridge National Laboratory, Oak Ridge, TN, Summer, 1993.

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.

"Fuels and Chemicals from Municipal Solid Waste," a pamphlet, National Fertilizer and Environmental Research Center, Resource Group. Muscle Shoals: Tennessee Valley Authority, undated.

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).

Katzen, Raphael. Unpublished correspondence summarizing consultations on production of ethanol from municipal solid waste in Lincoln, NE, January, 1994. Katzen and Associates, 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.

Lambert, R.O., J.R. Watson, J.D. Broder, M.R. Moore, R.C. Strickland, M.J. Beck and J.W. Barrier. "Economic Evaluation of TVA's Dilute Acid Process for Ethanol Production from Tennessee Valley Hardwoods." Muscle Shoals, AL: Tennessee Valley Authority, National Fertilizer Development Center, undated.

"Lincoln in the Chips with Christmas Tree Recycling Program," The Lincoln Star, Lincoln, NE, February 11, 1994.

City of Lincoln/Lancaster County, Department of Public Works, Steering Committee, Phase I. "Summary of Recommendations, Comprehensive Solid Waste Management Plan." Lincoln, NE, March, 1992.

City of Lincoln/Lancaster County, Department of Public Works, Steering Committee, Phase II. "Summary of Recommendations, Environmental Management Plan." Lincoln, NE, March, 1993.

City of Lincoln, Office of Recycling. "Summary of Solid Waste Generated and Recycled in Lincoln & Lancaster County, FY 90-FY 91 Through FY 92- FY93." Lincoln, NE, Fall, 1991, updated on request.

Lynd, Lee R., Janet H. Cushman, Roberta J. Nichols and Charles E. Wyman. "Fuel Ethanol from Cellulosic Biomass." Science, American Association for the Advancement of Science, March, 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).

Moore-Bulls, R.O. Lambert and J.W. Barrier. "An Evaluation of Hydrolysis Technology for the Conversion of Cellulosic Feedstocks to Ethanol and Other Chemicals," presentation to the Seventh Canadian Bioenergy R&D Seminar, April, 1989. Muscle Shoals, AL: Tennessee Valley Authority, Office of Agricultural and Chemical Development, Biomass Branch.

National Renewable Energy Laboratory. "Biofuels: Program Plan, FY 1992-FY 1996," Golden, CO, January, 1993.

SCS Engineers. Draft Solid Waste Management Plan for the State of Nebraska, South East Region, Department of Environmental Quality, Lincoln, 1992.

Sask Report. Untitled article on Pound-Maker Agventures Ltd. "Integrated Feedlot/Fuel Ethanol Facility Project in Canada," January/February, 1992. (Copy supplied by Raphael Katzen Associates International, Inc., Cincinnati, OH)

Solar Energy Research Institute. "Ethanol from Biomass: Just the Facts," pamphlet, Technical Information Program, Development and Communication Office, Golden, CO, March, 1991.

U.S. Department of Agriculture. New Crops, New Uses, New Markets: Industrial and Commercial Products from U.S. Agriculture, 1992 Yearbook of Agriculture. Office of Publishing and Visual Communication, 1992.

"Washington State Waste Paper Ethanol Plant Urged," Biologue, September, 1991.

"Waste to Energy National Inventory." U.S. Department of Energy, Office of Technical and Financial Assistance, Office of Conservation and Renewable Energy, November, 1992.

"Waste Cellulose to Ethanol Conference Proceedings." St. Louis, MO: October, 1992.

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