306 11/22/78

CONF-770368

NO STOCK

Conference Proceedings

Biomass—a Cash Crop for the Future?

A Conference on the Production of Biomass from Grains, Crop Residues, Forages and Grasses for Conversion to Fuels and Chemicals

March 2-3, 1977
Kansas City, Missouri

Funded by
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Solar Technology

April 1978

Under Contract No. EY-77-X-02-5009

NOTICE

Available from the National Technical Information Service, U. S. Department of Commerce, Springfield, Virginia 22161.

Price: Paper Copy $12.50
Microfiche $3.00

CONF-770368
UC-61

Conference Proceedings

Biomass — A Cash Crop for the Future?

A Conference on the Production of Biomass from Grains, Crop Residues, Forages and Grasses for Conversion to Fuels and Chemicals

March 2-3, 1977
Kansas City, Missouri

Funded By
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Solar Technology
Washington, DC 20545

Under Contract No. EY-77-X-02-5009

April 1978

BIOMASS - A CASH CROP FOR THE FUTURE?

A Conference on the Production of Biomass from Grains, Crop Residues, Forages and Grasses for Conversion to Fuels and Chemicals.

March 2-3, 1977
Kansas City, Missouri

WELCOMING REMARKS

John McKelvey, President

Midwest Research Institute

Welcome to Kansas City and to the Midwest Research Institute/ Battelle Biomass Conference. We're here under the sponsorship of ERDA--The Energy Research and Development Administration--because what biomass is all about is energy.

Since this conference was announced a few months ago, I've been asked the same questions a dozen times. "What is biomass? Doesn't sound like anything from any farms I know about. What's biomass got to do with the energy crisis?" These are good questions. They go right to the point of why these two days are so important to all of us--because there is an energy crisis.

All you have to do to convince yourself of that fact is to look at this past winter. A million-and-a-half people have been laid off because their companies couldn't get the natural gas or the oil they needed to keep plants open. The president asked all of us to set our thermostats at 65 during the day and 55 at night. I think a great many people have done so. I know we did at MRI and so did the other companies in this region. In Buffalo they have had how many hundred inches of snow? I've lost track. And they had to close the schools in Columbus. In the Midcontinent Region and in the Rockies, we've had the coldest winter ever with little or no rain or snow. We may be entering a drought at the same time that winter is forcing us to increase our energy consumption.

The energy crisis is real. We can see it. It's all around us... in the newspapers...on television. There are more reports every day of how energy--or the lack of it--affects us.

We can feel the energy crisis, too. We can feel it in the cooler temperatures at the office or at home, in the sweaters we're already accustomed to bringing to work, and we can feel it in our finances. Our heating bills are up, our electric bills are up, and our gasoline bills are up. If it takes energy, its price is going up.

And it's not going to get any better--the worst is yet to come. Parts of this country still have an abundance of natural gas. What's going to happen when the energy "haves" are asked--or ordered--to give up their reserves to the energy "have-nots?" What's going to happen when natural gas becomes so rare that we can't afford to heat our homes with it? What's going to happen when power plants, factories, light industries can't at any price get the gas they need to stay in operation--the gas they need to keep people working?

I don't know. And, I'd be surprised if anybody in this room knew--or if anybody in Washington knew. Because right now, the only thing we all know is that the energy crisis is with us right now, and is not part of a business conspiracy. But while we can see and touch the problem, that's not enough.

What we can't see and touch are the solutions. We don't know how to eliminate the energy crisis. We don't have any pat answers. We don't even know all the questions.

But we do know that the long-range solutions to the problem are going to require us to think in new directions. We know that no single area of research is likely to supply all the answers. But rather the ultimate solution is going to be a combination of solutions--each contributing something to the whole.

Our resourcefulness is being challenged to the limit by the demands for energy--today. In laboratories and test facilities all across the country, researchers are looking at new and old sources of energy. They're looking at atomic fusion, at windmills, at ocean tides and temperature differences, at solar panels, and at turning coal into gas and oil shale into usable petroleum.

And they're looking at biomass. Biomass is a new word in our vocabulary. It's a word whose importance in the energy picture is certain to increase, because biomass holds great promise as one of those new directions for energy research. It can be part of an answer that ultimately eliminates the energy crisis.

A few minutes ago, I said that people have asked me about biomass. They want to know what it is. By tomorrow afternoon, all of you will know about biomass and its potential. For now, I'm telling people that biomass is any plant, or plant leftover, that can be grown within the limits of conventional agriculture and can then be converted into some form of usable energy.

Biomass can be as exciting as a new hybrid grass or grain--or as dull as corn cobs. It can be the straw from wheat cattails--or even giant reeds. The point is that vegetation that once was considered waste, or even weeds--and was plowed back into the ground--now is being looked at for its energy content.

That's what brought all of us together today. In these two days, you're going to hear a great deal about biomass. There will be many opportunities to ask questions--and I hope you will. And I hope you'll leave Kansas City with some new ideas of your own that can be implemented wherever you live.

Thank you all for coming. I'm looking forward to a most interesting meeting.

ERDA'S FUELS FROM BIOMASS PROGRAM

Dr. Roscoe F. Ward, ERDA,

Division of Solar Energy

What I would like to do is present an overview of what is currently happening within our program in order to provide a basis for understanding what we are trying to accomplish and how we expect to accomplish it.

Fuels from biomass has as its goals and objectives to investigate and demonstrate the feasibility of utilizing agricultural, forest and animal residues to produce clean fuels and petrochemical products. We make a big differentiation between residues and wastes. Wastes are something that you have to get rid of, that you will pay to get rid of, whereas the residues we are dealing with have an economic value and we are going to have to, in most cases, pay to obtain these. So there is a big difference in the treatment and the processes. We would like to develop and demonstrate the technology for the economic production and harvesting of terrestrial and aquatic biomass. We are not limiting ourselves to soil-based agriculture only, but we are also investigating marine forms of agriculture.

We want to perform research, demonstration and development on the processes which show potential for economic conversion of terrestrial and aquatic biomass. We want to try and develop research and technology for the production of hydrogen, biophotolysis and photoelectrolysis. These last two processes are ones that have come under my and the other program manager's jurisdiction. Also, we need to try and provide the nation with some petrochemicals and other energy intensive products.

If we look at the program, we really talk about three parts. We talk about the sources, we talk about the conversion processes that we can utilize, and we talk about the end products.

People seem to envision that the fuels from biomass program has an endless source of funds, that we can fund every project around the country, and they don't understand our resources are limited. This year we have about $12.7 million. About $4 million will go into production research and the balance of that into conversion research. President Carter has upped these funding recommendations for next year to about $20 million.

To try to get some sort of perspective, we often think in terms of current residues, as providing a value of unity. Our present estimates are that maybe we can produce 10 to 15 times that number using marginal lands or other areas. And aquatic biomass is a number we haven't even tried to define.

Many people come in and say, well, how about using municipal wastes? If you try and put a value on municipal wastes, that is only about one-tenth that value of current residues and again there are a number of problems with these.

We have had these series of systems studies on terrestrial biomass. Battelle Columbus reported last fall on their sugarcane, sugarbeets and sweet sorghum study. The Mitre Corporation had a review two weeks ago on silviculture. The MRI and Batelle projects are part of our third study on grains and grasses and corn. We do have some field experiments underway and starting. We are trying to use the systems studies as a basis to determine what the opportunities are and whether we even should ask Congress for funds in this area. In other words, we are trying to determine a basis and a potential utilizing these studies.

We are off already into harvesting equipment. This is a cooperative undertaking with the forest service as well as with a number of other industries and with ERDA taking a major portion of the funds. There has been a harvester developed which will be utilized for cleaning up woodland areas, which will produce chips, which we can utilize as a fuel source. So we do have some active contracts which are trying to take care of some of the immediate needs.

Aquatic biomass is an area in which we have some field studies going on. This will be the last of our systems studies which will try and provide the overview for us of the potential of the total area.

If we look at the conversion processes in a little more detail, this is the general scope of the processes that we are investigating.

Anaerobic digestion is the one process that we are currently putting most emphasis on. We have requested proposals for a pilot plant which will process about 40 tons of animal residues per day. We have a number of experimental facilities which are operating now. Hamilton Standard is operating a facility at Greeley, Colorado, at the large Mumfort lot. Ektope, of the State of Washington, has a dairy digester and a joint agreement with the USDA at Clay Center. We have a series of supportive research and development projects at universities.

Another conversion process we are looking at is fermentation. Thus far we have only emphasized enzymatic hydrolysis. All of these fermentation projects are laboratory projects at the present time. A lot of these processes are relating to alcohol and other petrochemical substitutes. Again we are interested in proposals in the area of acid hydrolysis, as we feel this has some potential.

A third conversion process is biophotolysis. This is a longer-term project. The purpose of the project is to examine direct production of hydrogen by biological means. This is one of our projects off for the future.

Liquefaction is the fourth conversion process we are investigating. We have a project which was started under the Bureau of Mines which is now in startup.

Photoelectrolysis is another conversion process we are currently investigating. We have three projects currently in this area.

Part of the reason for the systems studies is to determine if fuels from biomass is economically viable. What we have to try and do is take the biomass production value and link it to a conversion process and see what sort of value we obtain for the fuel produced. For example, we are working now with animal manures. The estimated value that we feel we are going to have to pay for animal manures is from $1 to about $4 a ton. Using current technology, our estimates from a study which Dynatech has completed for us indicate that we can produce natural gas at about $2 a million Btu's using manure. We would have been glad to have had this methane at $2 a million Btu during this past winter.

But if we look toward the longer term the agricultural crops and give that $1 a million Btu and then decide to go anaerobic digestion, this will cost $3 a million Btu. Are we really willing to pay this price and can we really produce it in quantities that are significant in the long term?

These are all prelimniary figures. We hope that this conference will provide some better figures and some better information upon which to base decisions in the future. The goal of ERDA is to try and commercialize these processes in order to help with the energy needs of the country.

I would emphasize for those in industry that the policy of ERDA is if there is ever a decision between a university or a government lab or industry, the decision will be made for industry. The reason for this is that we feel that the only way we can commercialize these processes is by working with industry.

AN AGRONOMIST'S VIEW OF BIOMASS PRODUCTION

Dr. Dale N. Moss, Professor of Agronomy,

University of Minnesota

An agronomist dealing with any kind of crop situation summarizes his thinking in three different areas. The first is, what is the desired product. The second is, what particular genotype of a particular plant species will we be dealing with. Varieties of corn or varieties of wheat, these things become very important in any agronomic situation. And thirdly the agronomist deals with management. How do you take this particular variety of a particular crop and get it to function to give you the desired product?

What is biomass? Let me give you a little bit different definition of it. The product we are really dealing with is carbon to carbon bonds. These carbon to carbon bonds are where the energy comes from. And it's these bonds that we have got to worry about when we are talking biomass from an agronomist's point of view. The process by which we get those carbon to carbon bonds is, of course, the process of photosynthesis.

In the process of photosynthesis we are dealing with two separate photo acts. What happens in a green plant is that you have networks of chlorophyll molecules. It turns out that there are about 200 of them associated in a network which is known as Photo System II. These chlorophyll molecules are sort of wired together in such a way that if one of those chlorophyll molecules is able to capture a quantum of light, a photon, then it is able to shuttle that energy to a trapping pigment. Then you can use that energy to extract an electron from the water molecule. You bleed the water molecule, and release oxygen in the process. Also in the process this electron is pushed to a more negative EMF, it has more chemical potential energy. Then there is a whole series of compounds along which this electron flows in getting down eventually to Photo System I. In the process of moving through these compounds, ADP, a compound with two atoms of phosphate per molecule is changed to ATP, a compound with three atoms of phosphate per molecule. This is one of the kinds of energy currency that the plant uses. This ATP has a high energy phosphate bond and the plant is able to extract energy from that to perform certain synthetic processes.

The electron eventually ends up in another complex of a couple of hundred molecules of chlorophyll, known as Photo System I, and you get a second quantum of light absorbed. The electron is again kicked up to a more negative EMF. You eventually end up with the compound ferredoxin, where you have the reducing potential to reduce the compound NADP, giving you an end product of NADPH. Here again there is a high energy bond in this NADPH and the plant can utilize that bank of energy, then, to perform various processes.

The Calvin scheme of photosynthesis, developed by Melvin Calvin, explains further the process of photosynthesis. First the carbon dioxide enters the plant. It enters because you have a compound in the plant called ribulose-1.5-diphosphate, which in the presence of the proper enzyme will react with carbon dioxide. An important point is that in order to get to this ribulose-1.5-diphosphate you must have ATP. In fact, the ribulose-1.5-diphosphate has a high energy phosphate bond which was formed by extracting the energy from ATP.

ATP is again consumed in the conversion of 3-phosphoglyceric acid. Also, NADPH is consumed in order to convert to glyceraldehyde-3-phosphate. So you can see the energy that has been stored in the electron capture process then is used to make carbon to carbon bonds and to make interconversions in the plant.

From what happens in the photosynthetic process and from other reactions that must go on in plants we can calculate that it takes about 10 photons of light energy in order to reduce one molecule of carbon to the average reduction level that we find in plants. Or if we look at this in a larger unit that's more convenient to work with, we see that 10 einsteins of red light are utilized to reduce one mole of carbon dioxide to the average reduction state found in plants. And it is a very simple thing to calculate the energy contained in these 10 einsteins, since only visible radiation is used in the process of photosynthesis. The amount of energy that is contained in 10 einsteins is about 520 kilocalories. And if you take this mole of carbon that you formed and put it in a calorimeter and burn it, you will find that it will give up about 105 kilocalories of energy. Then if you simply take the ratio of the amount of energy available from the carbon in the plant by the amount of energy used to produce this carbon, you will come out with the fact that the process of photosynthesis has a theoretical efficiency limit of about 20%. Now, that's true if we are correct in the various assumptions that we make when we say there are 10 quanta required in order to get one molecule of carbon into the plant.

Across the visible range sunlight has a fairly flat distribution. Of the total energy in sunlight about 45% of it lies in this visible range and about 50% is in the infrared range. And only the visible portion is effective in the process of photosynthesis.

There is one other thing we have to deal with when evaluating the plant's efficiency for turning solar energy into carbon bonds and that's the fact that if you have a plant cover and solar radiation coming down on those plants, not all of the radiation is availble for use by the plants. There are various things that happen to the radiation, but the one we need to look at is the reflection of radiation from the plant cover. About 10% of the radiation that strikes a leaf is reflected back.

What does all this mean? Solar radiation is about 45% visible if you take the total solar spectrum. Leaves will reflect about 10% of the visible and we talked about the theoretical efficiency of the photosynthetic process itself is about 20%. You simply multiply these things together and you get 0.45 times 0.9 times 0.2 for a theoretical efficiency for a plant cover of about 8%. So if we had plants functioning absolutely perfectly in the field, we could have an 8% solar collector. That's the kind of limit we are working with.

Now, can anything be done about that? Absolutely nothing as far as we know. All plants use the same process to fix their carbon ultimately. It even happens in some of the bacteria that they run a very similar kind of program not utilizing chlorophyll, but we don't know of any way of getting these carbon to carbon bonds other than the one we have outlined. In fact, it looks like in terms of the energetics of the process that this is about the limit that we are faced with.

We want to talk now about how plants use the system that they have. It turns out that plants use their photosynthesis system quite differently. According to how they use their system, plants can be broken down into two basic groups, the C3 and C4 plants.

Orchard grass, red clover, sugarbeet, tobacco, wheat, oats, barley, all of our temperate grasses, and many other crop plants would fall in the C3 group. They have two characteristics. One is that at about one-third or one-fourth the intensity of full sunlight an individual leaf of these species becomes saturated with light. You can add more light to that leaf and you don't get a faster rate of CO_2 fixation. The second characteristic of the C3 group is that the amount of carbon dioxide entering the plant is about 20 or 25 milligrams per hundred square centimeters of leaf per hour.

The C4 group of crops responds quite differently. This group consists of corn, sugarcane, sorghums, all of the tropical grasses, a lot of dicot species, the common redroot pigweed, and many other plants. They have a photosynthetic system in which they are able to capture much more carbon dioxide given the same amount of light.

Now that may sound inconsistent with what we have said earlier, but it turns out that these C4 species have developed an interesting evolutionary trait that aids them very much. One of the difficulties of running the photosynthetic system in plants at all is the fact that they get their carbon from the air, and there is very little carbon dioxide in the air. The process of photosynthesis, during any period of intense light, operates at a CO_2 deficit. One way to increase the photosynthesis is simply to provide more carbon dioxide.

Well Mother Nature has done this in certain kinds of plants, the corn plant and others being examples. What occurs in the corn plant is a peculair arrangement of cells in the leaf. You have the vascular bundle which you can think of as being a cylinder of pipe and then out from this pipe you have fingers sticking. Around this pipe is a very solid cylinder of very prominent dark green cells and then out from this cylinder of cells actually you have fingers sticking out into the air spaces of the leaf. It turns out that the kinds of arrangement has been put together where you have a differentiation in terms of the type of cell and you have a differentiation in terms of the type of chemistry in these different cells.

These finger cells, which are called mesophyll cells, sticking out into the air, have a very large surface to absorb carbon dioxide. The carbon dioxide reacts with a compound known as phospho-pyruvate, usually called in this country phosphoenolpyruvate. But at any rate, what you end up with is a reaction of carbon dioxide with a high energy phosphate bond that is derived from ATP. You end up with oxaloacetate. This is quickly converted to the compound malate. This compound contains four carbon acids which is why these type plants are called C4 plants. You have combined carbon dioxide with a three carbon compound and gotten a four carbon compound, malate. The plant then shuttles this malate very quickly into the cylinder of bundle sheath cells around the vascular bundle. Once the malate gets in there, there is an enzyme which knocks off the carbon dioxide. The pyruvate is then shuttled back out. In this whole process all that has been done is the carbon dioxide has been fixed at the surface of the slant and moved to the inner cells and released.

So in other words this whole process is a mechanism for concerntrating carbon dioxide. It is actually a biological CO_2 pump. You extract CO_2 out of the air at a very low concentration, shuttle it into the cells and release it. The experimental evidence tells us that you end up with a higher concentration of carbon dioxide in the cells where the same photosynthetic process we have been talking about then occurs. The important thing is this permits the plant under proper environmental conditions to operate the photosynthetic process very rapidly.

There are other things that differ between the C3 and C4 groups of the plants. If there were a concentration of, say, 25 parts per million carbon dioxide around a wheat plant, it would have no photosynthesis. In fact, it turns out that in low concentrations of carbon dioxide wheat will lose carbon all the time. It respires just like man does. But corn at that concentration will be fixing some carbon dioxide. It will have a positive photosynthesis.

Now, you can take these two plants put them in a system, close it in, give them a fixed amount of carbon dioxide, turn the light on, and let them compete for what carbon dioxide is there. The corn plant will simply take the carbon dioxide away from the wheat and soon the wheat plant will die. This competition for CO_2 becomes the basis of a very simple way for seeking plants which have this particular corn-like photosynthesis.

We have used a system like this to screen literally hundreds of thousands of wheat, barley, potatoes, soybean plants, looking for one of these that might have this capacity to fix a larger amount of carbon dioxide in bright light. It turns out we can't find any genetic diversity for this capacity. And I wanted to present this particular story to point out that the agronomist can wish for a lot of things, but you can't work with it unless you have got something to work with. And first off, you have got to find some genetic diversity. That's true of whatever you are going to deal with, disease resistance or whatever. And in the case of this type of photosynthesis we simply have not been able to find the genetic diversity.

We tried another way to increase leaf photosynthetic rates. We simply measured lots of plants and tried to characterize the speed with which they are able to fix carbon dioxide. The purpose of these measurements was to select those which are superior, and then hopefully cross these and get plants that have a greater ability for photosynthesis.

After we measured the photosynthetic rate of various plants, we ranked them accordingly. This ranking seemed to indicate a reasonable degree of genetic diversity. However when we employed the Duncan's multiple range test, it indiciated that there's a great deal of variability in this kind of measurement. In other words the variations we found in photosynthetic rate could most probably be accounted for by chance. Now, we are not just sloppy workers in Minnesota. This happens all over the world whereever these kinds of measurements have been made. What gets even more discouraging is when we changed the temperature by 5 degrees our ranking went all to pot. So selecting plants for an enhanced ability to fix carbon is a very discouraging process indeed. We have not learned how to do that yet. So this is one area that an agronomist would like to deal with in terms of greeting new varieties that inherently do a faster job of what they have to do. But we are not able, at least in this point in time, to produce these new varieties.

Under the best of conditions we are faced with the fact that plants work at about 4-1/2% maximum efficiency and so they end up being far below the 8% theoretical maximum we were talking about earlier. So we probably do not have to worry about that particular limit. The thing we do have to worry about is how to get them to perform at least to this 4-1/2% level, which we know they are capable of doing.

We have made a lot of measurements of photosynthesis of wheat and barley and many other kinds of crops. Through these studies we obtained a lot of infomation which shows photosynthetic rate as a function of time of year. It increases to a maximum in about mid-June, and then falls off very quickly.

Now if we take our data and plot the amount of photosynthesis as a function of the amount of leaf that's over the land, it turns out that plants will continue to increase their photosynthetic rate as their leaf area is increasing. This rate then decreases as the plants are beginning to mature.

What does this say? It says simply that in order to get maximum growth rates, to get this high photosynthesis, we have got to come up with some kind of a scheme of keeping a large leaf area over our land. And in terms of management for biomass this becomes our very big problem.

We have attempted to keep a large leaf area over land by combining crops, and even in Minnesota there is some potential of double cropping. We planted rye in the fall of 1973 in one experiment. Then, we harvested it on the 30th of May. We planted corn on the 15th of June. We would have planted it on the 30th of May, but it began raining and we couldn't get back on the land. And we harvested that after frost at the end of the growing season.

The point is that the corn produced in the area of biomass about 9 tons per acre of dry matter, but it produced the same amount by planting a little bit later than the usual corn planting date, as it would have done by devoting this land solely to corn. By putting winter rye in and using this early season, April and May, when corn wouldn't grow if you planted it and, in fact, when it has no leaf area at all, we could increase the total biomass production by almost 40 or 50%. We simply provided a leaf cover there early in the season that would function in cool weather.

I would also like to say just a little bit about some other kinds of things we have done. One of our favorite agronomic crops in Minnesota is the cattail. I have almost gotten chased out of the profession by growing cattails. But we have grown some in some little paddies. The cattail is a plant which has a shoot growing up and a large storage organ which is about 4 to 12 in. beneath the soil surface.

The rhizome is the underground stem of the cattail. The cattail packs this rhizome full of starch. The cattail turns out to be kind of an interesting plant for two reasons: it has a very high productivity in terms of biomass and it's a very efficient producer of starch. Starch is a very good chemical to go a number of directions from. If we are talking about saving energy, using starch as a chemical feedstock might be an interesting way to save a lot of energy in the country.

Another interesting thing about the cattail is that it carries a lot of leaves and it distributes these leaves in space so that light can hit the surface of those leaves all the way down to very near the bottom of the plant.

It turns out that the cattail will produce about 20 tons of dry matter under Minnesota's conditons in a season. I want to compare this yield with what an agronomist would say is our highest biomass producer in the State of Minnesota, the corn plant. If we get a very good corn crop, it would yield 150 bushels per acre. We convert that into biomass yield and count the root systems in, assuming that 20% of that plant will be underground, and we come out with a biomass yield of about 10 tons per acre.

Question: Is there any difference in the quality of cattail and corn as concerns their energy content?

Answer: It turns out you can look at a very wide array of plant materials and they will all come out to have an energy content of about 7,000 Btu's per pound. Plants do the same kinds of things. They have got to have some proteins and fats and other various things in order to function. There are lists of maybe hundreds of species where the variations in energy content is quite small, as little as plus or minus 5%.

Question: What percent starch is your rhizomes?

Answer: We have not looked at the percentage starch. The literature would tell us that it's somewhere in the neighborhood of 65% at maturity. I don't know whether that's true of the plants we grew or not, but that wouldn't be far off.

Question: You began to allude to bacterial photosynthesis. Would you care to expand on that or any other comments?

Answer: Not in the short time we have available. Sulfur bacteria uses sulfur as an energy course. They extract an electron from the sulfur rather than from the water, but they run a similar photosynthesis process to what we have in green plants and the energetics is about the same.

Question: One thing I think you ought to point out to those who have gone to the other meetings is the difference between you using air dried tons and the oven dried tons we have used in some of the other studies.

Mr. Benson: Yes. At least in our studies we have used the air dried ton of biomass as a measurement of yield and that is with the biomass material dried in air to its nominal air dry value of somewhere in the order of 12 to 18% moisture content. I understand that some other studies have used oven dried figures.

Dr. Moss: The figures I used were oven dried figures.

UTILIZATION OF LAND WITH LIMITED CAPABILITIES

Dr. A. D. McElroy

Midwest Research Institute

The focus of our program is approximately 1 billion acres of land devoted to agricultural production as cropland, pasture, and rangeland. A major part of the program is devoted to determining where this land is and what it is used for, as well as determining what one might do differently to enhance the production of biomass.

Toward this end, we have taken advantage of information and data developed in considerable variety and detail, primarily by the Department of Agriculture, with the Soil Conservation Service playing a very important role. Particularly important is the Conservation Needs Inventory of 1967 in which agricultural land throughout the country is categorized by land use. These categories are crops of different types in pasture, range, woodlands, farmlands and roads idle or under conservation use. The land is also described in this inventory in terms of its production capabilities, which are called land capability classes. There are eight major classes and four subclasses, and there can be as many as 29 land use classes. This is a tremendous county-based data system on computer tapes, so one can use it as the basis for a variety of analyses.

The land capability classes are directly related to the current use of the land as well as to its capabilities and serve as the basis for developing altered production modes.

To further fill out the background of data and information, we have used the Stanford Research Institute inventory of crops and crop residues, which SRI developed on a county-by-county basis and can be aggregated in different ways. We have also taken 1969 Census of Agriculture information provided on a county-by-county basis and have integrated this into the data system.

An analysis of land utilization has the objective of describing and quantifying the land and its production capabilities. The analysis starts with the current situation and proceeds to an evaluation of possibilities for enhancing production capabilities through alternate utilization schemes based on differing crop scenarios and differing or increased utilization of land. The basis for these analyses is the various systems of information which describe both the capabilities of the land and its uses, with the analysis being particularly sensitive to possibilities for effecting greater utilization of marginal land, idle land, and land which might perhaps be better utilized for biomass production instead of continuing in its present use. We have chosen to use the land resource area (LRA), which divides the country into 156 areas, as the basic unit for analysis. At times it is convenient to use the land resource regions, which divide the country into 20 regions, since these regions generally represent land areas which are fairly homogeneous in character and agricultural use.

What do we mean by alternate or improved utilization of the land resource? We can think of using acreages which are now considered to be idle; that is, they are in conservation use or in estates which are not effectively used for agricultural production. We can also think of modified uses of land which is presently devoted to some productive use. For example, pasture or range might be diverted to more productive uses. One can consider increased use of wet soils which are not particularly suited for growth of corn or other crops. Adapted crops in semiarid areas might be considered for biomass production. A final option might emphasize the growth of high biomass yielding crops in present productive cropland acreage.

Table 1 gives the 1975 statistics on crop and hay land acreages. These statistics represent acreages planted to various crops or hay which have been harvested. Acreages are tabulated for wheat, corn, hay, soybeans, other small grains, the sorghums, cotton, tobacco, vegetables and fruits, and several crops which are lumped together as miscellaneous crops. Wheat and corn are the major crops, followed closely by soybeans and hay. Cotton and tobacco have not been included in our analyses of biomass production, nor have fruits and vegetables and most of the miscellaneous crops. In 1975, 347 million acres were devoted to cropland production. From 450 to 470 million acres are, however, included in what is called cropland in tillage rotation, as shown in Table 2. This acreage includes land in summer fallow, land in conservation, temporary pasture, and like categories, which are considered to be in the tillage rotation. An approximately equal acreage (about 465 million acres) is in pasture and range combined throughout the country. The three major categories--cropland, pasture, and range--add up to about 950 million acres, which in broad terms is the resource considered to be available for biomass and food production from grasses and grains. Included in the agricultural land category are 130 to 150 million acres of woodlands and forests within the bounds of farms, and about 30 million acres of land devoted to farmsteads, roads, barnyards, etc. The total acreage adds up to about 1.1 billion acres.

A further breakdown of this land is shown in Table 3. The acreages of planted and harvested grains and hay, including summer fallow, are usually in the range of 335 to 380 million acres. That land not specifically in cropland production, i.e., used as temporary pasture or in conservation use, ranges from about 90 to 130 million acres per year. Thus,

TABLE 1

1975 CROP AND HAY ACREAGES

	10^6 ACRES	PERCENT OF TOTAL
WHEAT	75	22
CORN	78	23
HAY	62	18
SOYBEANS	55	16
OTHER SMALL GRAINS	38	11
SORGHUMS	18	5
COTTON, TOBACCO	11	3
VEGETABLES, FRUITS	6	2
MISCELLANEOUS	4	1
TOTAL	347	

TABLE 2

ACREAGES OF FARMLAND IN BASIC USE CATEGORIES

	10^6 ACRES
CROPLAND	450-470
PASTURE, RANGE	460-480
	940-950
WOODLANDS, FORESTS	130-150
FARMSTEADS, ETC.	30

TABLE 3

UNITED STATES CROPLAND, PASTURE AND RANGE ACREAGE

	10^6 ACRES
CROPLAND	
PLANTED/HARVESTED GRAIN/HAY, INCLUDING CULTIVATED FALLOW	335-380
PASTURE USE, CONSERVATION, ETC.	90-130
PASTURELAND	
PASTURE	100
RANGE	365

about 25% of the land classified as cropland is not actually utilized for harvested crops. Permanent pasture land acreage is about 100 million acres, while about 365 million acres are classified as range.

The distribution of agricultural land among the various land capability classes is shown in Table 4. Most of the Class I land (36 million acres out of 42 million acres) is in cropland. The remaining 6 million Class I acres are mostly in pasture. The major portion of cropland, 380 million acres, is Class II to IV land. These lands have limitations which increase in severity from Class II to Class IV. The problems are classified as erosiveness, wetness, soil problems, or climate problems.

Permanent pasture occupies some Class I land (4 million acres); the majority of pasture lands (77 million acres) is on Class II to IV land, and most of the remainder occupies Class V to VII land. The majority of the rangeland is in the V to VII category, which means that most of the range occupies land not well-suited for production of tilled crops. About 100 million acres of range, however, is Class II to IV land.

In our analysis, we have proposed modified uses for part of the current pasture and rangeland. It is also recognized that the fraction of land classified as cropland, but which is not specifically used for growing crops in a particular year, is also underutilized; the acreage designated in the Conservation Needs Inventory as "other land not in farms" is also recognized as a potential resource. The following discussion is based on the presumption that these categories of land are in principle available for modified productive use.

Any analysis of possibilities for enhancing biomass production from grasses and grains necessarily has to be conducted within the framework of: (a) present uses and the economic/social values associated with these uses, (b) basic limitations to production such as topography, rainfall, and soil, and (c) the availability of adapted plant species which can give significant biomass yields as well as being able to cope with fundamental production limitations. As one can see from the data, we presently devote about 30 to 35% of all the land classified as agricultural land to tilled crops and to harvested nontilled crops. This acreage can hardly be considered to be underutilized and thus available for diversion to biomass-specific production, although it probably is true that not all of this land is being used to its fullest potential. At present one should consider that our prime agricultural land is best viewed in the context of combining food/fiber crop production with harvesting of crop residues for energy use.

TABLE 4

LAND USE DISTRIBUTION

	LAND CAPABILITY CLASS			
	I	II - IV	V - VII	VIII
CROPLAND	36	380	22	0.1
PASTURE	4	77	25	0.1
RANGE	1	97	263	4.5
OTHER LAND	0.6	12	7	
TOTALS	42	566	317	5

Approximately 100 million acres of the 450 million acres of cropland are not presently used for harvested crop production. This acreage is "idle" as far as crop production is concerned because it is being temporarily used for pasture, or is included in estates or investment tracts, or is classified as being under conservation, i.e., in some type of permanent cover. The acreage constitutes a reserve which would likely be used first if acreage of major food crops is significantly increased. How much of this might be made available for biomass production is unknown. We have arbitrarily indicated in Table 5 that 50 to 60 million acres could be available, and have further assumed that it would be primarily Class II to IV lands.

Inventories of agricultural land show that about 13 million acres (see Table 5) of land in Classes I through IV fall in the "other land not farms" category, which presumably includes such land as highway rights-of-way. It is perhaps reasonable to assume that 50 to 60% of this land could be put into production.

Permanent pasture, most of which is located in higher rainfall areas of the United States, occupies about 100 million acres, 81 million being in Class I through IV land--land which varies from having no limitations (Class I, 4 million acres) to severe limitations (Class IV) to tilled crop production. In principle, most of this land could be diverted to biomass production, with biomass crops ranging from row crops to small grains to permanent or perennial grasses or legumes as the limitations increase in severity. The pasture acreage (25 million acres) in Classes V to VII can probably be considered for biomass production only to the extent that it is practical and economically feasible to harvest "hay" from native or improved grasses.

Rangeland is by far the largest reservoir of land which might be viewed as being "underutilized." Here one must recognize that this land is vital to our livestock economy, and that the livestock segment of agriculture will dispute its classification as "underutilized." According to land inventories (see Table 5) 98 million acres are potentially tillable Class I through IV land, while 263 million acres are essentially nontillable (Class V through VII). Unfortunately, most of the rangeland is in low rainfall areas in which one cannot think in terms of any but modest biomass yields. Nevertheless, one should not thrust aside this land as being unsuitable for biomass production unless irrigation is provided, but one should evaluate this land as a potential resource for producing drought-adapted plant species. The extensive research on guayule may, for example, furnish the basis for formulating biomass scenarios for arid lands having 15 to 20 in. of annual rainfall. Similarly, dry-land adapted plants such as giant reed may provide a species for utilization of rangeland which has rainfall of the order of 20 in/year.

TABLE 5

"UNDERUTILIZED LAND"

	10^6 ACRES		
	CLASS I	CLASS II - IV	CLASS V - VIII
CROPLAND		~ 60	
PASTURE	4	77	25
RANGE	1	97	263
OTHER	1	12	7
TOTALS	6	246	295

About 25% of the approximately 550 million acres defined as underutilized land occurs in the eastern part of the country where annual rainfall exceeds 25 in.; about 50% is located in areas with 16 to 25 in. of rain, and the remaining 25% receives less than 15 in. If rainfall were the only criterion (i.e., if soil, topography and climate do not limit production), the higher rainfall areas should be capable of biomass yield of 3 to 5 tons per acre on an average and considerably higher in limited areas; the median range should be capable of from 1 to 3 tons per acre, and the lower rainfall areas will generally produce less than 1 ton per acre per year. Since the underutilized or marginal land usually has some basic limitation to productivity, attainment of such yields may not be at all possible much of the time, and will generally in other areas require the use of crop management techniques which limit economic feasibility.

With regard to the problems associated with better utilizing the marginal land, approximate percentages of different land classes are as follows: IIe-IVe, 28%; IIw-IVw, 8%, IIs-IVs, 5%; IIc-IVc, 5%; Ve-VIIe, 28%; Vw-VIIw, 2%; Vs-VIIs, 22%; and Vc-VIIc, 3%. The IIe-IVc and w lands thus comprise about 36% of all underutilized land, and these would likely be principal candidates for utilization for biomass production. The Ve-VIIe and w land, about 30% of underutilized land, would be more difficult to bring into production. The lands with soil (s) and climate (c) limitations would not likely be considered as candidates for biomass production.

In summary, some 500 to 600 million acres of the U.S. agriculture resource is currently not in crop or hay production, much of it deservedly so. These acres are, for the most part, seriously limited when viewed in terms of cultivated crop production. The shifting reservoir of cropland not in crops, 75 to 100 million acres, should most readily adapt to biomass-for-energy production; these acres are inventories as part of the crop/hay production resource, and there is the danger that indiscriminate shifting into biomass production will impair crop production capabilities. The 12 to 13 million acres classified as other land in farms is a potential resource, whose ultimate value is lessened by its diffusivity, but which presumably could be brought into production without impacting crop and hay production. Permanent pasture, 100 million acres, of which 80 million is Class I to IV land, is a significant potential resource, located mostly in higher rainfall areas. Finally, about 100 million acres of rangeland is potentially tillable Class I to IV land, but these acres are located primarily in arid to semiarid parts of the country. Diversion of the potentially available underutilized land into biomass production will be in conflict with other beneficial uses, both for crop production and for livestock production, and this basic issue must be carefully analyzed. The principal technical problem consists of finding and adapting combinations of biomass crops that are the most practical and economical and employing cultural practices necessary to insure significant and lasting productivity, since a majority of the underutilized land has one or more problems.

QUESTION: I have two specific questions.

One, have you included acreage for sugarbeet and sugarcane? I couldn't guess where you put it.

DR. McELROY: The acreages are included in overall analyses of land availability. The MRI study does not, however, include sugarbeets as a biomass product.

QUESTION: Second, did you include the tillage land in Hawaii, Alaska and Puerto Rico?

DR. McELROY: No, we did not.

QUESTION: What is the cost of bringing land in various classes under production?

DR. McELROY: We have not got into that in any detail. We do know that erosion control, for example, can be costly enough to have a serious impact on production costs. This is a topic which has to be evaluated in depth, but in relation to other production and conversion costs.

QUESTION: I was wondering if some of the land might be overutilized. For example, you showed 22 million acres of cropland in the Class V to VII category. Is it possible that some of that ought to be changed from cropland to other uses such as range or pasture?

DR. McELROY: There are indeed fairly large acreages of land with "serious" limitations, by CNI criteria, in cropland. It would appear that some of this land is "overutilized" and might in fact be put to better use--perhaps for biomass production. For example, marginal land now in grain crops might be better used to grow perennial grasses or sorghums--if a market for the biomass were available.

QUESTION: Is the concept of the correct level of utilization keyed to sustain yields under present agronomic practices? How is that actually defined?

If you start to classify land as to whether it's utilized correctly or underutilized or perhaps overutilized, just what is the criterion? Is it sustained yields at current inputs?

DR. McELROY: The Department of Agriculture classifies land on the basis of its ability to sustain yields over the long haul, and our analysis is keyed to this criterion. The correct level of utilization will surely require modification of present agronomic practice--for biomass production--ranging from adapting and using biomass-producing species, which are tailored to deal with land limitations, to implementation of measures such as conservation practices aimed at maintaining land capabilities.

QUESTION: Were the millions of acres of idle land associated with our interstate system considered? Our 40 some thousand miles of interstate highways are associated with a tremendous land acreage, some in the heart of the richest country. This is idle land on which biomass could be produced. Did you consider this at all?

DR. McELROY: I'm not sure how that land fits into CNI definitions and inventories. I would guess that land probably fits in the category of "other land not in farms," If that's true, we have included that land as available or underutilized land.

QUESTION: You would have the same problem with idle land in urban areas.

DR. McELROY: Right.

QUESTION: Is there any plan for updating that 1967 Conservation Needs Inventory?

DR. McELROY: I asked that question of USDA in Beltsville 3 or 4 months ago. The answer was a qualified yes, but I understand that forthcoming inventories will differ substantially in format from the 1967 inventory. USDA does have in progress another inventory, which might be available within 2 or 3 years.

QUESTION: May I address that just a minute? The USDA Soil Conservation Service is putting out a potential cropland study which is based on a sampling of the original 1967 CNI and that will published this year.

BIOMASS POTENTIAL FROM UNDEREXPLOITED SPECIES

Dr. A. D. Allen
Midwest Research Institute

Now, underexploited crops, you probably wonder what the term means. Actually, underexploited crops could mean a lot of things. A hundred years ago red, spring wheat was an underexploited crop. Seventy-five years ago soybeans was an underexploited crop. Fifty years ago flax in California was an underexploited crop. These are crops that have been grown in other portions of the world, but then are adapted to new uses or new areas.

In this context, we have looked at the crops that could be grown for their hydrocarbon content, have been used as a source of fibers, or perhaps even as ornamentals. Now, each of you I'm sure can think of other types of crops such as pigweed thistle or Johnson grass. All of these are fairly good biomass producers and have been evaluated.

A plant which you have seen in the news recently has been Dr. Melvin Calvin's gasoline plant, which is a Euphorbia species. Articles originally quoted him to the effect that this plant would produce from 10 to 50 barrels of oil per acre, however, I think the correct statement that he had given was from 2 to 20 barrels of oil per acre. This specific plant is a small desert bush which grows in the semiarid areas of California. Currently, there is not enough information to properly evaluate this plant so it is not included in this evaluation, but it is an interesting crop and I am sure that you will hear more about it.

I first want to mention some of the factors that would make an underexploited crop into an economically viable crop.

Factors Affecting the Establishment of a New Crop

One of the factors that influence the introduction of a new crop is the genetic variability of a crop and how flexible it is. For example, when a crop is first introduced, it may have been selected from some primitive agricultural area or from cultivated crops grown in another country. As these underexploited crops are selected for high biomass yield, we will see some variability within varieties grown under the new conditions.

An example of this was safflower when it was first introduced in California. One species was introduced from the Sudan and one from Egypt. As growing experience progressed with this plant, selections were made from the Sudan introduction which was a very good variety and today there is none of the Egypt species being grown.

Another interesting feature is the conditions under which these crops thrive. For example, it has been found that the grasses that grow under the more stressful conditions such as along the margins of forests and on hillsides are much better adapted plants than the grasses that grow out in the middle of the grassland areas.

As the pressure of planting increases with new crops, the biomass yields will be variable because consciously or unconsciously selections will be made.

Crop Design and Growth Pattern

One of the most important features in a new crop, of course, is its design and its pattern of growth. The nature of seed production is also important. Does it grow from seed or from vegetative propagation? If it does require vegetative propagation, then this increases planting costs and it almost forces it to be a perennial plant so that the plantings will last for quite a bit longer.

Plants selected for high biomass yield should be energy conserving. Energy conserving plants are those that do not require excessive amounts of irrigation or excessive amounts of fertilizer and can be grown under adverse conditions or on the poorer types of land referred to as underutilized land. These plants should be able to withstand soil conditions when the soil moisture is below the wilting point and still have the ability to withstand conditions such as being covered with water, which may cause damping off or root rot of the plant.

One of the new crops that has been introduced in the recent past has been the castor plant. When it was first introduced it was a plant that made a very rank heavy growth with seeds that matured at different times. This resulted in their shattering out, so there were very few seeds left on the plant at harvest. By the process of selection, the internode distance on these plants has been shortened, the plant has been reduced, and those plants that were more uniform in the maturity have been selected. However, they have defeated the purpose of our requirement for biomass production as we want a ranker growing plant. Therefore, the castor plant is now not as good a biomass producer as it was at one time, but the harvesting is much easier.

Another plant that has not been popular for its intended use as a bast fiber plant was the ramie plant. This plant is a good fiber plant, but because of difficulty of extraction of fiber, other plants such as kenaf, expresso grass, and similar crops have become more important.

Genetic Adjustments

The introduction of a gene for shorter internodes, for example, has made it easier to harvest castor beans. Selection for this factor has also been accomplished with corn. We could see, therefore, how if we selected a corn plant for a longer internode we might perhaps reduce the corn grain yield slightly but would have a more suitable dual purpose crop--one that would give us a higher stover yield while still producing substantial quantities of corn grain per acre.

Another problem that is associated with genetic adjustments is genetic erosion. When a specific characteristic is selected, often the erosion of another desirable characteristic occurs. The best way that this is controlled is by keeping the original gene base in its original form located in seed banks, one of which is located at Fort Collins, Colorado.

It is possible to make the synthesis of a new crop through gene combinations. One of the crops in which this has occurred is corn. Corn originally had an ear on the tassel but through selection the ear was moved to the middle of the stalk. Other crosses such as wheat and rye have been combined to form the hybrid tricalate.

Some of the more desirable combinations would perhaps yield plants with distinctive vegetative or agronomic characteristics which would be adapted to greater temperature extremes or to moisture stress. In plant adaptability another point to consider is the planting and harvesting machinery. Can we use shelf machinery or currently available machinery? If so, it is only a matter of adaptation. Or does it require major revisions. Occasionally, a whole new line of machinery has to be developed as for the castor plant. It requires two different items of machinery for harvesting. One, a harvester, and the second, a huller in order to handle this plant. On the other hand, safflower and sunflower can be handled with conventional machinery.

Some of the yields of these underexploited crops are quite heavy and they would strain the capacity of the harvesting machinery currently available. It would require much heavier duty and higher capacity machinery in order to handle these high biomass crops.

If we are considering a plant such as cattail, which is grown in a peat bog, it is necessary to have a machine that has flotation principles in order to harvest the aerial portion. Also, if we want to harvest some or all of the underground rhizomes, then it is necessary to have a second type of harvester for this portion of the plant.

Some of the additional requirements of harvesting machinery are these machines increase the bulk density of a harvested crop to make it easier to transport. This would include higher density bales, pelleting, cubing, wafering, chopping and self-formed stacks.

Moisture content becomes very important in the harvesting of all immature and mature growing plant material. The moisture content may run as high as 90% in some plants, especially aquatic. It is very difficult to air dry these plants with very high moisture content as usually there is also a high humidity in the area. Therefore, some type of compressing or dewatering must be used.

Another important point in growing a crop is success. Naturally to be continued to be grown, a plant must be successful. If unsuccessful over an entire area where it is planted, a crop will be discarded. Usually in experimental plantings of any crop, some crop failures will occur but normally there will be enough high yields to override this. An examination of the growth and the culture practices that the successful growers have followed indicates successful management practices for sustained area production.

I will just touch on markets and marketing arrangements. The conversion plants would be the most readily available market for these new crops. These conversion plants would be strategically located in the center of the main production area. The marketing arrangements with the producers would very likely be some form of contractual arrangement.

It is a necessity to provide for a sustained market to have sufficient acreage available. It would require consistent acreage that could be available on a year-around period.

It is necessary to have some type of promotion and advisory service to carry the new crop information out to the people and promote its successful attributes. Of course, with our present communications this is handled fairly rapidly. You recall some of the problems in the Southwest and the blackland area of Texas when they were running into problems with the sorghum aphid. Until the sorghum aphid resistant varieties were developed, many producers changed over to sunflower production. It did not take very long for this change. Some of the basis for this rapid change could be traced to another study which MRI conducted where we found that over 50% of the producers get their crop information from the elevator operators. In this instance, it did not take very long for these producers to find out that the money was in a new crop, sunflowers, and not in nonaphid resistant sorghums. Therefore, promotion of a new crop does not take too long if the economic benefits are present.

Occasionally it is necessary to provide a subsidy for a new crop. Sponsorship by industry may be necessary and if this does not produce enough interest, then subsidies by the government may be a necessity. This has occurred in two instances with strategic war materials. One was in the payments for castor beans during the Korean War. When the price per pound varied from 6 to 10 cents, the acreage reflected almost directly the price subsidy. However, in Canada when the subsidies were removed from rapeseed the acreage dropped, but sponsorship by industry has stimulated an increase in the production of rapeseed.

Pests are always an important consideration with a new crop. Kenaf has a very serious root nematode problem and it could well be a limiting factor in widespread production. However, some of the chemicals for the control of corn rootworm could perhaps be used for basis for some control. Oftentimes many pest control treatments for similar crops can also be utilized for pest control on the new crops. Diseases which affect a specific crop may also be regional. For example, the castor plant, which in its place of origin, Africa, is badly affected by rust; is not affected by this problem at all in the United States.

Crops which have been selected for their economic value as food or fiber producers may well be adapted for biomass production. Kenaf is a bast fiber product which is used to a limited extent as a non-wood crop for paper pulp production. Considerable time and interest has been invested in this crop over the last few years. The USDA currently has two persons in Savannah, Georgia, working full time on this crop. The growth region for this crop extends generally over the same area that corn and soybeans can be grown. The yields vary from about 15 or so tons in the Southeast on down to about 2-1/2 tons in the extreme northern area of the corn belt.

Culture practices with kenaf are very similar to corn in that it is an annual row crop. Harvesting is generally done with the same machinery used to put up corn silage.

Another very similar crop is roselle. However, it does not have the desirability as a bast fiber producer as kenaf, but is a little longer growing plant or later maturing plant. It also has a superiority in that it is relatively resistant to the root knot nematode which is quite a problem with kenaf. Therefore, it has to be considered as a replacement plant for kenaf in those areas where the nematode problem is severe.

The next crop is one that has been known since biblical days, the very interesting plant called giant reed, Arundo Donax. This particular plant is used primarily today as a source of reeds for woodwind instruments. France traditionally has grown the best quality reed which are the preferred reed by many musicians. Also, the crop has been grown in Italy for utilization as an ingredient in rayon manufacture. This crop generally grows best in the warmer areas; but it can stand quite a bit of cold temperature during the dormant period; however, if a freeze occurs after initiation of spring growth, it will kill the plant back. Giant reed is a perennial which is planted from root sections of vegetative cuttings.

Under present conditions, giant reed does not offer a potential as a cultivated crop in the U.S. for any use other than biomass, therefore, very little interest has been taken in growing this crop in the U.S. except for erosion control, shelter belts or ornamental.

Among the non-woody rapidly growing plants, this species is one of the highest producers of cellulose. The yields on it vary depending on soil fertility. Some interesting yield estimates from various areas run up to as high as 40 to 50 tons of dry matter per acre. However, these yields are considered to be far above average. Yields on this plant will probably average in the 12, 15, 18 ton/acre category and to a much lesser extent in some of the other areas where the soil is less fertile. For example, in Argentina in some studies on infertile land, yields were 4 tons dry matter per acre, on fairly fertile land 6 tons, and on fertile land 8 tons per acre.

This plant has a large root or rhizone system and has the ability to go down to considerable depths to get water. After it is planted it requires some moisture for the first year, but after the second or third year, it is very drought resistant and can withstand a considerable amount of drought. In nature, cane is able to flourish on soils that are apparently very infertile. On the other hand reed has the ability to respond well to nitrogen fertilizer to maximize yields. One of the strong points of this crop is that it can make good growth without additional fertilizer under conditions of low rainfall. Reed might require additional water some time during its first year as it can be seriously retarded by lack of moisture during this period, but drought does not damage stands 2 or 3 years old. It has about a 3-year period to get into full production and about a 10-year productive life.

In the U.S. there are reports by Gaylord Container Corp. that show fairly good wild stands of reed along the Rio Grande River yielded about 8-1/3 tons oven dried matter per acre and the poorer wild stands yielded about 5-1/2 tons oven dried material per acre.

Plants adapted to wet buggy areas are typified by cattail, a plant which grows well in most temperatures if wet enough. The aerial yields are usually about 1/3 to 1/2 of the total yield with the remainder being roots and rhizomes. Harvesting can present a problem as it is grown under such different conditions than crops which are currently being grown.

The next crop to be discussed is guayule. This is a semiarid desert shrub which makes maximum growth under rather adverse conditions. This crop was grown under the direction of Forest Service during World War II to replace the foreign sources of rubber which were disrupted during the war. A plant was built in California for producing rubber from this shrub for use in tires. At the present time, there is a rubber manufacturing plant in Mexico that is supposed to go into production using the wild guayule shrub in that area.

Guayule is a shrub that grows best between 15 and 25 in. of rainfall under semiarid conditions. It can grow under conditions of less moisture than that, but it must be irrigated during a critical period following transplanting. It is somewhat limited in its growth area because it requires warm weather and is not very cold resistant. Usually the Great Bend area of Texas is about as far north as it will grow. Both the plant and the roots are harvested, since both have a high hydrocarbon content. This plant is a perennial and has a life cycle of from 3 to 5 years.

Another crop which is very similar to guayule is the hybrid of guayule and mariola. This hybrid has a better adaptation as far as cold weather goes than does guayule and therefore may be grown somewhat farther north. However, the hybrid does not have as high yields of latex as hydrocarbon content, but it does have a greater mass of shrub growth than guayule alone.

As far as yields go, we have extrapolated these from many sources. I want to point out that these were extrapolated yields or anticipate yields because all these crops are not grown throughout their adapted area. For example, we had the USDA bulletin on kenaf which contained actual yields in various areas with this information extrapolated to the entire growth area. These data were also used for roselle. For the giant reed we used the literature reports. For guayule we used quite a considerable volume of material that was accumulated during and following World War II, and for cattail we used Minnesota data.

So, realizing this limited information was inadequate, inexact and insufficient, nevertheless, we placed these new crop yields into our data base and came out with the adapted crop for biomass production on nonfood producing cropland which was indicated to be the best performance for each land resource area.

Plant Species for Biomass Production on Marginal Sites I. Forage Grasses and Legumes[1/]

W. F. Wedin and Zane Helsel[2/]

Introduction:

Grasses and legumes for biomass production add an additional use to their present, multiple-use characterization. In contemporary agriculture and closely related activities, we know these important plant species are of value for pasture and forage, soil and water conservation, wildlife cover, recreational areas, roadbank stabilization, and their aesthetic qualities.

Production of grasses and legumes on marginal sites (marginal for row-crop production) is dependent on soil productivity (including fertilizer applied), plant growth factors (solar radiation, temperature, carbon dioxide, water), genetic potential, plant pest control (weeds, insects, diseases), and the cropping system. Land use considerations are very important and this constraint in itself cautions against an intensive monoculture of annual forages (grasses or legumes), regardless of their productive capacity for biomass or other uses.

[1/] Presented at "Biomass - A Cash Crop for the Future?", A Conference on the Production of Biomass from Grains, Crop Residues, Forages, and Grasses for Conversion to Fuels and Chemicals. Kansas City, Missouri, 64110, March 2-3, 1977.

[2/] Professor and Instructor, Department of Agronomy, Iowa State University, Ames, Iowa, 50011.

Production Sites:

Acreages in the U.S. are extensive for rangeland, pastureland, cropland used only for pasture, and grazed forests that are privately owned (Table 1). In addition, federally-owned lands, managed by the Forest Service and the Bureau of Land Management, are extensive.

Table 1. The grazing land resource in the United States.[1/]

Privately-owned	Acres (Millions)
Rangeland	380.5
Pastureland	103.2 (3.2)[2/]
Cropland used only for hay or pasture	77.7 (13.0)[2/]
Grazed forests	137.2
	698.5
Federally-owned	
Rangeland	262.7

[1/] Includes Alaska, Hawaii, and Caribbean area

[2/] Irrigated

[3/] Reference: Blakely and Williams (1974) and USDA (1971)

The U.S.D.A. Conservation Needs Inventory of 1967 (1971) cited extensive needs for lands in all land capability classes, i.e., from I to VIII, and Blakely and Williams (1974) pinpointed these for the grazing land resource. They further pointed out that hay or pasture cropland represents 11 percent of the total forage resource and much of this occurs on soil sites of high productivety. That land in the higher capability group may be pushed into row-crop production, at the expense of depleting the forage resource, is a prime concern. This concern has been discussed by Long (1974) and Wedin et al. (1975).

Considered herein, in terms of yield potentials, are sites presently used in perennial or annual grass-legume production in the Northcentral region (NC) of the U.S. Reported for this region in 1968 was 48 percent of all the hay produced in the U.S. Wedin and Vetter (1970) . The area includes over 100 million acres in pasture.

Climatic Conditions:

The states in the NC region vary markedly in average annual temperature, average annual precipitation, frost-free days and relative humidity (Figure 1). Increased precipitation, as compared to areas more western, was a main factor in causing the tall grasses to dominate the prairie vegetation. The prairie vegetation was associated with soils which were highly fertile, resulting from organic matter buildup and decreased leaching.

Range of Grass and Legume Species:

Grasses and legumes considered for their biomass yield, and as used as forage in many instances, have been drawn from a wide range in germ plasm. For the grasses, they are represented by 600 genera, of which 150 occur in the U.S. These 150 genera include 1500 species. For legumes, there are approximately 400 genera and over 12,000 species. There are about 80 grasses and legumes to which significant attention has been given. In the NC region, this list is narrowed considerably (Table 2).

When grown for forage purposes, grasses and legumes are harvested by grazing or machine (hay, silage). While yield *per se* has often been used as a criterion of worth, the forage quality (nutritive value and implied intake) has been a desired factor, often being chosen in leiu of added yield (biomass

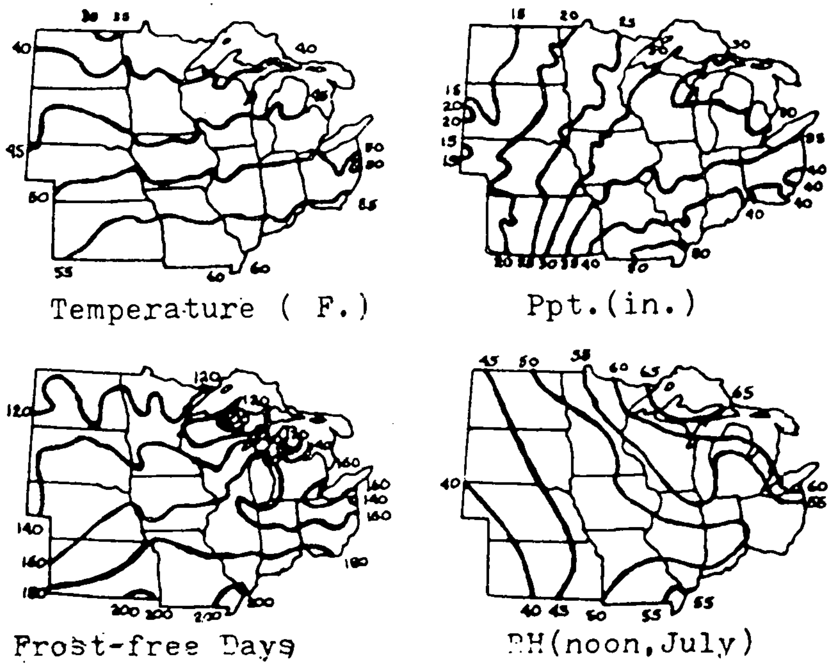


Figure 1. Climatic Conditions in the NC region. (NC Reg. Res. Publ. 166. 1965.)

Table 2. Forage grass improvement in NC Region.

Orchardgrass	Wheatgrass (Int., Crested, West., tall)
Smooth bromegrass	Creeping foxtail
Reed canarygrass	Timothy
Tall fescue	Switchgrass
Sudangrasses	

production). From the data available, then, we must speculate, theorize, or extrapolate to what yields are biologically possible in biomass production. What is economically feasible is also of prime concern but can perhaps be answered once we know the yield potential.

While only a few of the grasses used presently would be candidates for economic biomass production, selection and improvement within the grasses could evolve better cultivars to meet the requirements of a crop grown for its biomass only on marginal soils. For example, perennial grasses are largely fibrous-rooted, may propagate vegetatively to form soil-conserving sods through vigorous rhizomatous, stoloniferous, and tillering characteristics. Within their areas of adaptation, they are long-lived plants, and they tolerate disturbance.

Search for grasses for biomass should not exclude too quickly the various types of grasses. Nonetheless, from an ecological standpoint, Harlan (1959) has cautioned that there are distinct differences between native or introduced grasses and legumes. He pointed out that natives are climax species and the introduced sub-climax. As such, the sub-climax or introduced ones, thrive under disturbance, respond to higher fertility levels, have efficient means of seed production, withstand grazing and mowing, compete well under use, establish readily in clean seedbeds, and tend to disappear when not used.

Off-setting this thinking is the fact that warm-season crop plants, which includes perennial grasses such as switchgrass (Panicum virgatum L.) are C_4 plants, i.e., they fix carbon dioxide more efficiently in terms of light utilization in photosynthesis. Reed canarygrass (Phalaris arundinacea) a cool-season perennial grass, is a C_3 species and has a reduced efficiency in light utilization because photorespiration occurs, which dissipates up to 50 percent of the fixation of these C_3 plants. Nelson (1976) has pointed out that the C_3 species has the advantage of a longer growing season.

The two afore-mentioned factors, i.e., ecological characterization and photosynthetic-efficiency characterization have immediate and long-term advantages, respectively. Stated another way, among the perennial grasses ready to be used soon in biomass production, the search should be on those introduced species with associated technologies that are workable, while the longer look should be at the potentially more efficient species. For this comparison, we have examined data relative to biomass production of reed canarygrass and switchgrass. In addition, a C_4 annual species, Sorghum spp., is considered.

Reed Canarygrass:

This grass is well adapted to poorly drained soils, tolerating flooding for more than a month. It has also been shown to be productive on uplands when adequately fertilized with nitrogen. It does well under dry conditions. It is very winter-hardy, but frost-sensitive. It's perennial nature permits early spring growth. (8 inches of growth is common by May 10 in central Iowa.) It may reach a height of 6 feet or more when fully headed. Stems of reed canarygrass are stout and resist lodging. It grows well on most soils and will tolerate a pH range of 4.9 to 8.2.

Yield data, representative of the potential production of reed canarygrass, are presented in Table 3.

Table 3. Yield potential of reed canarygrass.

Location	Cuts	Yield (Tons DM/A)	N (pounds/A)	Reference
Conn.	4	4.79	190	Decker et al. (1967)
New York	4	6.11	190	Decker et al. (1967)
Penn.	4	4.23	190	Decker et al. (1967)
Maryland	4	4.10	190	Decker et al. (1967)
Iowa	3	6.32	480	Wedin et al. (1970)
Iowa	3	1.69	60	Wedin (1966)
Iowa	3	4.13	240	Wedin (1966)

It is evident that reed canarygrass responds markedly to nitrogen fertilization. We obtained yields near Ames, Iowa, in direct proportion to rate of application (Table 4) and split applications were beneficial.

Table 4. Yields of reed canarygrass at varying N rates.

Early Spring	Early June	Aug. 1	Tons DM/A
0	0	0	1.24
0	0	120	3.16
60	60	120	5.41
0	0	240	4.00
120	120	240	6.32
0	0	480	5.51

We had other tests on reed canarygrass in southern Iowa, and looking at this data with that from the Ames study, we documented a marked residual nitrogen response, which increased the next year's yield. When the yields of a late-fall harvest (November) plus the early-June and late-July harvests of the following year were totaled, it was evident that the first increment of N (120 pounds per acre) was the most efficiently used. Response of species differed (Table 5) with reed canarygrass using nitrogen more efficiently, particularly at higher levels of nitrogen application (Wedin, 1974).

Table 5. Dry matter produced in pounds/pound N applied in early August at two Iowa locations.[5/]

	Increments of N applied in lb/A		
Harvests[1/]	First 120	Second 120	Third & Fourth 120[3/ 4/]
November	17.0	3.3	0.9
Early June	8.9	9.3	2.5
Late July	1.9	2.6	7.7
All harvests	27.9	15.1	11.0
Species[2/]			
Reed canarygrass	31.8	22.4	17.4
Smooth brome	23.9	19.8	10.4
Tall fescue	28.6	12.8	8.2
Orchardgrass	27.1	5.5	8.0

1/ Four species averaged
2/ Totaled over three harvests
3/ Represents an additional 240 lb/A applied
4/ Tall fescue and orchardgrass had some winterkilling at one location
5/ Wedin (1974)

Sorghum spp:

The common sorghums used for forage are sudangrass ((*Sorghum bicolor*), formerly *S. sudanense* (Piper) Stapf), the sorgos and grass sorghums, *S. bicolor*, and grain sorghums *S. bicolor* (L.) Moench. These grasses are coarse and erect; height will sometimes reach 10 feet. The forage sorghums will be taller yet. They are well-adapted for marginal sites throughout the country, but of course must be re-seeded each year. Of the sorghums grown, approximately 25 percent are for forage.

Because the sorghums contained a glucoside (dhurrin) which under conditions in the rumen converts to hydrocyanic acid (prussic acid), considerable selection and numerous management practices have been aimed at reducing this potential. Yield *per se* may have thus been selected against, in some cases.

Some yields of *Sorghum spp.* which have been obtained are presented in Table 6.

Table 6. Yield potential of *Sorghum spp.* in Iowa.

Species	Cuts	Tons DM/A	N Rate (#/A)	Reference
(Forage Sorghum)	1	7.8	90	Burns & Wedin (1964)
(Sudan)	1	3.0	90	Burns & Wedin (1964)
(Forage sorghum)	2	5.8	90	Burns & Wedin (1964)
(Sudan)	2	4.8	90	Burns & Wedin (1964)
(SXS)	1	6.3	120	Wedin (1970)
(SXS)	3	2.8	150	Wedin (1970)
(SXS)	1	8.5	150	Adigun (1969)

Noted is the highest yield from forage sorghum (7.8) and a sorghum x sudangrass cross (SXS) at 8.5. Forage sorghum was reduced in yield when two cuts were taken but sudangrass yielded more with two cuts (4.8) than one cut (3.0).

There is a strong possibility that other species within the diverse sorghum germplasm would be excellent biomass producers. White et al. (1974) described the potentials of sorghums as a source of pulp. They studied nine accessions representing three sorghum species. These were grown at six locations in the U.S., and greatest yields were in Iowa, Indiana, and Georgia. Yields exceeded 10 tons of dry matter per acre (12.2 in Iowa). One accession of Sorghum almum yielded 11.0 tons of dry matter per acre. These were 12-inch row plantings. The researchers pointed out that performance varied considerably within and among accessions and among locations. Also pointed out is the wide variation which results from effect of environmental conditions on annuals.

A further consideration must be made in relation to possibilities that a vigorous Sorghum species such as S. almum may develop it's perennial characteristics to the extent that it would become a weed, i.e., a plant out of place. Appropriate caution would be in order if it were to be grown for biomass.

Switchgrass:

This tall, perennial sod-forming grass has as its natural habitat the Great Plains area. It grows to 5 feet in height; has short rhizomes which promote spreading. It is one of the easiest native grasses to establish; a common problem with the warm-season perennial grasses. It produces well on droughty, infertile, eroded soil. Improved cultivars are available.

Within the last decade, switchgrass has been more commonly grown on Iowa and Missouri sites. When fertilized with nitrogen, yields have increased and are typified by those given in Table 7.

Table 7. Yield potential of switchgrass.

States	Cuts	Tons DM/A	N Rate (#/A)	Reference
IA	2	2.8	0	Schaller (1975)
IA	2	4.4	120	Schaller (1975)
IA	2	4.3	240	Schaller (1975)
MO	1 or 2	2.7	60	Matches (1976)
MO	3	5.0	?	Anderson et al. (1976)

Generally, it is expected that a species such as switchgrass could yield considerably better as rainfall increases. The grass has not, in practice, been grown for its total dry matter production, and in this respect, yields now being obtained when water and nitrogen are available must be carefully evaluated. Further, Rechentin (1956) has pointed out that the morphology of switchgrass suggests that it is not an ideal grazing plant because there are only two to four short basal internodes, suggesting few basal buds available for recovery. On the other hand, allowing switchgrass to produce one crop, which could then be removed, is likely to be both advantageous to maximizing annual dry matter yield and maintaining the plant for the following year.

General Considerations:

Climatic conditions suggest that rain-fed biomass production from grasses will be maximized when moving from west to east, more particularly from northwest to southeast in the NC states, or Corn Belt. This area is also the leader in row-crop production, machine-harvested forage for large ruminant livestock industries, and where improvement of long-term pasture offers great opportunities. For perennial grass use in the ruminant livestock industry, along with its harvested forage and pasture needs, this should be regarded as complimentary with biomass production. Some of the same inputs which will make the beef industry profitable in the future will likely be of benefit economically to biomass production. Use of legumes for nitrogen needs of grasses, double cropping (Helsel, 1976), fostering proper land use to minimize environmental insults, interseeding and overseeding, devising new cropping systems over years, are but a few of the important ones for the decades ahead.

LITERATURE CITED

Adigun, Ebenezer Oye. 1969. Dry matter accumulation and in vitro digestibility of pasture-type sorghums as affected by planting dates. Unpublished Master of Science thesis. Iowa State University, Ames, Iowa.

Anderson, B., M. Mitchell, and A. G. Matches. 1976. Management of warm-season grasses. Res. Rpt. (Special) 192. Southwest Missouri Center, Univ. of Missouri. pp. 44-46.

Blakely, B. D., and R. E. Williams. 1974. Our grazing land resources. Chapter 2 of Grasslands of the United States, (Ed.) Howard B. Sprague. Iowa State University Press, Ames, Iowa, 50011.

Burns, J. C., and W. F. Wedin. 1964. Yield and chemical composition of sudangrass and forage sorghum under three systems of summer management for late fall in situ utilization. Agron. J. 56:457-460.

Decker, A. M., G. A. Jung, J. B. Washko, D. D. Wolf, and M. J. Wright. 1967. Management and productivity of perennial grasses in the Northeast: I. Reed canarygrass. West Virginia Agr. Exp. Sta. Res. Publ. 550T.

Harlan, J. R. 1959. Plant exploration and the search for superior germ plasm for grasslands. Chapter 1 of Grasslands -- American Association for the Advancement of Science Publication 53, Washington, D.C.

Helsel, Zane. 1976. Double cropping experiment harvests first crop as forage. Crops and Soils 28(8):24.

Long, Robert W. 1974. Future of rangelands in the United States. J. Range Mgt. 27:253.

Matches, A. G. 1976. Growing legumes with warm-season grasses. Res. Rpt. (Special) 192. Southwest Missouri Center, Univ. of Missouri. pp. 32-33.

Rechentin, C. A. 1956. Elementary morphology of grass growth and how it affects utilization. J. Range Mgt. 9:167-170.

Nelson, C. J. 1976. Agronomic potential for biomass production. Third Annual UMR-MEC Conference on Energy. University of Missouri - Rolla.

Schaller, F. W. and S. J. Murdock. 1976. Switchgrass production. Annual Progress Report (1975) Shelby-Grundy Experimental Farm. Iowa State University. pp. 5-6.

U.S. Department of Agriculture. 1971. National Inventory of Soil and Water Conservation Needs (1967). Statistical Bulletin 461.

Wedin, W. F. 1974. Fertilization of cool-season grasses. Chap. 5 (pp. 95-118), Forage Fertilization. Mays, D. (Ed.). American Society of Agronomy, Madison, Wisconsin, 53711.

Wedin, W. F. 1970. Digestible dry matter, crude protein, and dry matter yields of grazing-type sorghum cultivars as affected by harvest frequency. Agron. J. 62:359-363.

Wedin, W. F. 1966. Legume and inorganic nitrogen for pasture swards in subhumid, microthermal climates of United States. IXth International Grassl. Congr. Proc., Sao Paulo, Brazil. pp. 1163-1169.

Wedin, W. F., H. J. Hodgson, and N. L. Jacobson. 1975. Utilizing plant and animal resources in producing human food. J. Animal Sci. 41:667-686.

Wedin, W. F. and R. L. Vetter. 1970. Pastures for beef production in the western Cornbelt, U.S.A. XIth International Grassl. Congr. Proc., Brisbane, Australia. pp. 842-845.

Wedin, W. F., R. L. Vetter, and I. T. Carlson. 1970. The potential of tall grasses as autumn-saved forages under heavy nitrogen fertilization and intensive grazing management. Proc. of the New Zealand Grassl. Assoc. 32:160-167.

White, G. A., T. F. Clark, J. P. Craigmiles, R. L. Mitchell, R. G. Robinson, E. L. Whiteley, and K. J. Lessman. 1974. Agronomic and chemical evaluation of selected sorghums as sources of pulp. Econ. Bot. 28:136-144.

Question: You mentioned that if you have to supply nitrogen fertilizer that represents, of course, an input of energy which is more or less opposed to the objective of the cultivation of the crop in question.

Now, I would like to suggest that when you grow legumes in combination with a grass, for example, that you are doing the same thing, perhaps not as severely, because even though the nitrogen gas is free, the fixation is not. In fact, it is very expensive. So you are really utilizing solar energy for fixing nitrogen that otherwise would go into the straight biomass production of the grass.

So it seems to me we have to look at such a system very carefully to see whether we are really ahead.

Answer: Right. That is a very good point. And I wanted to mention the fact that we want to look at the overall balance of energy input to energy output. And the other problem with legumes is in general they do not provide this nitrogen, quote, perhaps as efficiently to the grasses and the overall crop canopy in this general area would not be as productive as the grasses alone with the nitrogen input.

And I think that it is a very important point to make. We are spending some energy even with the legumes, not perhaps for nitrogen fertilizer, but from the plant material itself or from the energy from the sun to collect this nitrogen, so to speak, from the air by the legumes.

Effect of Removal of Crop Residues on Soil Productivity

W. D. Shrader

Return of all crop residues is essential for the continued productivity of some soils. On other soils alternatives are available so that crop residues can be removed and productivity maintained or increased.

This paper is concerned with defining and locating soil areas on which alternatives to return of crop residues are or are not feasible, describing the uses and limitations of the alternative procedures and in making realistic estimates of the kinds and quantities that might be available.

Role of Crop Residues

Crop residues are a valuable source of soil nutrients. Larson et al. 1976 estimates that the residues from 9 leading crops in the United States contain about 4 million metric tons of N, 0.5 million metric tons of P and 4 million metric tons of K. This amounts to about 40%, 10% and 80% of N, P, and K, respectively, of current fertilizer application to all crops.

Crop residues, if properly managed, can greatly increase water infiltration rates. On a soil developed under prairie, Mannering and Meyer 1963, found that final infiltration rates were increased from 2.3 to 5.3 cm/hr when 1 ton per acre of wheat straw was placed on the soil surface. On soils that developed under forest, surface seal is commonly much greater than under grassland and the increase from use of surface mulch thus more pronounced. On a forested tropical soil, Greenland 1975, found a 5 fold increase in infiltration when comparing surface mulch with the same mulch plowed under.

Maintainance of Soil Organic Matter

Return of crop residues or animal manure is the only feasible means by which soil organic matter can be maintained on cropland. In general, soils that developed in the humid east and southeast United States under forest vegetation were originally low in organic matter. In the midwest soils that developed under tall grass prairie were originally high in organic matter. Further west with declining rainfall, organic matter levels declined but were generally higher than under the eastern forested soils.

At the time the land was brought under cultivation, organic matter levels were at equilibrium. Over time, the additions of plant remains replaced the amount that was lost by oxidation or erosion. Under cultivation, the old equilibrium was lost. When no fertilizers were used most soils lost organic matter when cultivated. Soils that were originally high in organic matter lost more rapidly than low organic matter soils. Under any system of land use soil organic matter levels tend to an equilibrium point that is in balance for a particular rate of removal and addition of crop material. On the high organic soils of the Central United States, organic matter levels usually decline under a row crop system even when high rates of fertilizers are used. Over the past century, the corn belt soils are estimated to have lost about one-half of their original organic matter (Bartholomew et al. 1957 and Brady 1974).

Low organic matter soils may increase under cultivation even under continuous corn (Sutherland et al. 1961) but on most relatively high organic matter soils, organic matter levels decline. On Galva silt loam, a Typic Capudol in northwest Iowa with 5 percent organic matter (Barnhart 1977) found a 6 percent decrease from 1957 to 1976 under continuous corn where grain only was harvested and a 12 percent decrease in organic matter if all top growth was removed. About 8 percent of the crop residue added over the 20 year period was present in the soil in 1976.

Soil Structure

Soil structure, the degree and form of soil aggregation, especially in the surface soil is important in soil productivity. Well aggregated soils have high rates of water infiltration, are easy to till and tend to be more productive than soils with poor structures. On soils that are acid, low in bases and low in clay, soil structure is determined mostly by the organic fraction. This includes most of the soils that developed under forest in the eastern United States.

Many of the soils that developed under prairie are relatively high in clay in the surface soil, and the exchange complex of the clays are more than 60 percent saturated with bases (calcium and magnesium). On these soils the soil structure is in part determined by organic matter but to a large degree the soil structure and soil tilth are determined by the kind and nature of the clays.

Vegetative Control of Erosion

a) Water erosion

A complete cover of live vegetation furnishes almost complete protection from erosion even on very steep slopes. Erosion occurs on sloping incompletely vegetated land. Erosion is especially a problem on sloping land that is used for row crops such as corn and beans in the humid portions of the country because these crops leave the land bare during May and June, the period of maximum rainfall intensities. Any type of vegetative cover such as crop residues on the land surface help to control erosion.

Most studies indicate that erosion can be reduced about one-half by leaving all residue from a corn harvest on the surface as compared to removing the residue or plowing it under. An allowable soil loss of from 4 to 8 tons per acre per year is assumed in most areas to be the upper limit of permissible, or socially desirable erosion.

The Universal Soil Loss Equation developed by Wischmeir and Smith, 1965 is widely used and is the only accepted means of estimating erosion losses from large land areas. The equation is:

A = RKLSCP where

R is the rainfall and erosivity index

K is the soil erodibility factor

LP is a topography feature representing the combined effects of slope length and steepness.

C is the cover and management (rotation) factor

P refers to supporting practices

A is the estimated soil loss in tons per acre.

This equation estimates the average amount of soil loss from a given slope. It does not estimate the sediment delivery to a major stream. This delivery figure is usually less than the loss within a field.

Larson et al. 1976, used the Universal Soil Loss Equation to calculate soil loss within several Land Resource Areas in Minnesota and Iowa with present cropping patterns and with 3 levels of conservation tillage. Conservation tillage with 3360 Kg/ha of residue reduced erosion to about one-half the level with no residue but in all cases even with essentially all residue returned, erosion is in excess of the "permissible" soil loss. This finding is in agreement with earlier work of Coleman, 1953, who examined all available research data on runoff and erosion and concluded that there was no way to control erosion on row crops on sloping land without supplemental practices such as terracing or strip cropping.

Table 1 illustrates some of the problems of erosion control by cultural practices alone. According to the tables currently in use by the Soil Conservation Service, erosion cannot be controlled on slopes of over 2 percent without supplemental practices in LRA108 which is mostly in eastern Iowa and western Illinois unless the acreage of corn and soybeans is appreciably reduced.

If erosion, at least in the central corn belt, is to be kept within allowable limits with present cropping patterns, recourse will have to be made to practices such as terraces and settling basins.

Table 1. Maximum intensity of cropping at which soil losses can be held at 5 tons per acre or less in LRA108

% slope*	LS	C**	Cropping system	Permissible removal of corn residue: No terrace	Permissible removal of corn residue: Terrace
1	0.13	1.07	Continuous corn, no restrictions	All	All
2	0.20	.70	Continuous corn, no restrictions	All	All
3	0.29	.48	Continuous corn, Contour list on ridge	All	All
4	0.40	.35	Continuous corn, residues on surf.	None	All
6	0.67	.24	Continuous corn, fall chisel	None	All
8	0.99	.14	C - C - C - W - M - M	All	All
10	1.40	.10	CC - W - M - M	All	All

*Effective slope length = 100'

**Maximum value of C at which soil loss can be kept below 5 tons/a/yr.

b) Wind erosion

Erosion by wind is liable to occur on any incompletely vegetated land surface. It is most severe on sandy soils during periods of low rainfall and high winds. While not confined to that region, wind erosion is most prevalent in the western part of the great plains. McCalla and Army 1961 estimates that the following quantities of wheat straw are the minimum quantities of residues needed to control wind erosion:

Sandy to sandy loam soils	1925 Kg/ha
Silt loams	1320 Kg/ha
Silty clay loams	1100 Kg/ha
Clay loams	825 Kg/ha

These quantities of residues if left on the surface are sufficient to control wind erosion. Wind erosion control can also be aided by use of strip crops, rough tillage or, in special cases, by wind breaks.

Effect of Removal of Residues in Nutrient Needs

Much greater amounts of nutrients are removed in corn silage than in corn grain harvest (Anonymous. Silage. Potash News Letter, 1964). With corn grain yields of 7840 Kg/ha, 129, 22 and 28 Kg/ha or N, P, and K, respectively, would be removed from the soil. However, with the same yields and with removal of the whole plant, 224, 37 and 140 kilograms of N, P, and K, respectively, would be removed.

If the crop residue is used for feed or bedding, a portion of the nutrients are available as manures and can be returned to the land. If the residue is burned, the nitrogen is lost but phosphorus and potassium are left in the ash and can be returned to the land. There is only a relatively small amount (15 Kg/ha in the above example) of P in the residue. However, most of the K take up by the corn plant is still in the residue at the time of corn harvest. In the above example, there is 112 Kg/ha of K in the silage (140-28).

The amount of N, P, and K in plant residues would vary widely with the time of harvest and weather conditions after frost but prior to harvest. Much of the N and K are water soluble in the dry plant residue and if there is rain after frost but prior to removal of the plant residues, a large percentage of these nutrients will be washed out of the residue and into the soil.

Classification of Soils as to Their Dependence on Crop Residues for Maintainence of Productivity

Most of the major soils in the United States can be classified into one of two groups: Group A, soils whose continued productivity is more or less independent of their organic matter level and Group B, soils whose productivity is closely dependent upon the soil organic matter in the surface soil.

Group A. A large and agriculturally very important group of soils has physical properties that are generally favorable for crop production, and these properties are resistant to change by man. Soil structure, ease of tillage, infiltration rates and bulk density are favorable for crop production and are determined largely by texture and by the type of clays and the base status of the clays. Surface soil textures of this group are in the 15 to 30 percent clay range. The clays are of mixed, high exchange capacity mostly 2:1 lattice types and more than 60 percent of the exchange capacity is saturated with bases of which calcium is the dominant ion.

Most of them are Mollisols or Inceptisols with only slight to moderate subsoil development and most contain 2 percent or more organic matter in the surface soil. These soils are resistant to deterioration because of properties that are difficult for man to alter. They can be so compacted as to be reduced in productivity and they can be pulverized so as to be subject to surface seal, decreased infiltration and severe wind and water erosion. However, under most current management systems, tilth remains fairly good and usually does not limit crop yields.

Most group A soils have been in cultivation little more than 100 years. During this time most of them have lost 50 percent or more of their original organic matter content (Bartholomew et al. 1957 and Brady 1974). In general, the ones that were highest have lost the most and some of the ones that were originally very low in organic matter have gained some organic matter over the years.

The constant rise in crop yields over time on these soils independently of organic matter levels indicates that maintanence of soil organic matter while desirable, is not essential to their continued productivity. Since recently exposed subsoils that are devoid of organic matter have produced high corn yields, it appears that at least on some soil materials, there is no lower critical level of organic matter (Engelstad et al. 1961).

Erosion may occur whenever the rate of rainfall exceeds the infiltration rate of the soil. Bare soils even in this group develop a surface seal during intense rains which decreases infiltration, increases runoff and the opportunities for erosion.

On cropland throughout the regions occupied by Group A, soils erosion is estimated (Larson, et al. 1976) at about 12 tons per acre.

Wind erosion is liable to occur on any of these soils that are devoid of a vegetative cover in the spring and early summer. Wind erosion is more severe on the sandy and loamy soils than on the silt loams. Wind erosion can be controlled by cultural practices such as rough plowing even when all surface residues have been removed but control is much easier and more complete if residues are present.

Erosion, both from water and wind, increases the cost of production on these soils but results in none to a moderate loss of productive capacity. The offsite damage from water erosion can be prevented by use of terraces or catch basins that prevents silt from leaving the producing area even though soil movement within the field is at a rate of several tons per acre.

Thus, on this highly productive group of soils a considerable portion of the surface residue, such as corn stalks, and oat and wheat straw, could be removed from the land without reducing the lands production potential.

A large and agriculturally important group of these soils occupies what was tall grass prairie in the North Central States. This is area Land Resource Region M in Figure 1. There are large acreages of soybeans but the quantity of residue left after bean harvest is less than a ton per acre and is needed on the land to help control wind and water erosion. Even when all soybean residue remains on the land the cover is too sparse to be of much value. Interseeding of soybean fields with winter small grains by airplane has been tried. When fall rainfall is adequate to sprout the small grain, this practice is very helpful in controlling both water and wind erosion.

If corn residue was removed from the land the needs for K fertilizers would be increased probably by about a factor of 2. P fertilizer needs would be little different than if the corn grain only was removed from the land. N fertilizer needs would vary but would eventually be increased by 50 to 75 pounds per acre per year.

To the west of Resource Area M in Resource Areas F, G, H, and I, most of the soils are group A so far as physical properties are concerned and on irrigated land the statements made for the corn belt are generally valid. On wheat land a minimum of about 1000 pounds per acre (McCalla and Army 1961) is needed to help keep the land surface protected from wind erosion and help keep it receptive to the limited rainfall.

There are surpluses of wheat straw over the amounts needed for land protection in some years but the quantities available per acre would be less and the supply would be less reliable from year to year than for the supply of corn stover centering in the Illinois-Iowa area.

At the western edge of the Mollisols, the Brown soil regions of Wyoming, Colorado and New Mexico, the quantities of crop residue produced on non-irrigated land are frequently less than the quantities needed to keep the land protected from wind erosion. Therefore, except locally on irrigated land, surplus residues from cultivated crops are very limited westward from about the hundredth meridan (Central Nebraska).

Group B. Eastward and southward from the area of tall grass prairies, the prairies merge into forest vegetation and the soils are mostly Alfisols (gray-brown podzolic) and Ultrasols (red and yellow podzolic). These soils are easily damaged by management decisions. Included are medium to sandy textured, moderately to strongly acid soils low in organic matter. In this group of soils, organic matter is very important in maintaining a desirable surface tilth.

The group B soils, because they are on the eastern seaboard, were the first soils in this country to be farmed extensively. The plantation agriculture of the "deep" south developed on them as did the largely self-sufficient or subsistence farms of New England. These soils were always easily "worn out" and in areas such as in the tidewater areas of Delaware, Virginia and the Carolinas much of the land was always in timber and relatively small areas, were used for a few years and then allowed to "rest" under forest. Even so, the amount of cropland is less now than it was 100 years ago over much of the area occupied by the group B soils. This is in part because the physical condition of these soils deteriorates rapidly under some types of cultivation.

In general, organic matter maintainence or improvement is necessary for the continued productivity of these soils. Plow pans or traffic pans develop rapidly which increases soil density, reduces permeability and soil water holding capacity.

Some soils such as the red limestone soils of Lancaster County, Pennsylvania are maintained in a state of high productivity even though most of the corn is removed for silage. Manure resulting from the feeding of this silage is returned to the land. Some alfalfa is grown and lime is applied as needed so the soils are not strongly acid.

On this large and important group of soils, most of the crop residues are needed on the crop land to maintain productivity, either directly or in the form of manures. On similar soils in Europe, soil scientists recommend that soil organic matter needs to be maintained at a level of at least 1 percent organic matter for each 10 percent of clay (De Lenheer 1958).

Therefore, for the row crops common to the area, such as corn, soybeans, peanuts and cotton, essentially all residues are needed on the land and additional residue producing winter cover crops such as small grains or hairy-vetch is helpful in improving productivity of these soils.

A possible exception concerns the wheat straw that is produced in a double cropping system of wheat-soybean throughout the southeastern United States about as far north as Indianapolis, Indiana or St. Louis, Missouri. Where soybeans are planted directly into the wheat stubble, the stubble alone furnishes sufficient ground cover and in fact, the wheat straw that went through the combine and is returned to the land hinders establishment and cultivating of the soybeans. One to two tons of wheat straw per acre is available from this source. Use of this straw for energy would be in competition for its use as bedding, for mulching and for livestock roughage.

Analysis of Potential Supplies of Corn Residue in Land Resource Region M

Crop residue most likely to be available for energy production is in the cash grain areas of the corn belt in LRRM. Corn residues are most likely to be used because there are more of them than of any other type of residues, they are of limited commercial value at present for alternative uses and the potential supply per square mile or county is high. As previously discussed, most corn is produced on soils where the current supply of organic matter is not critical for their continued productivity. They have lost half of their original organic matter and corn yields are much higher than in the past and are still increasing.

Land Resource Region M covers much of the corn belt, the major potential source of corn residues. A wide variety of soil conditions are included in region M and a classification of their relative suitability on a Land Resource Area (LRA) basis is desirable.

The LRA's in Region M are grouped into 5 groups in Table 2 according to the suitability of the soils for furnishing corn residue for power generation.

The 77 million acres of land in the "good" and "moderately good" categories is the most likely source of supply. In this area the soils can be kept in a state of high productivity even though organic matter levels are declining and the soils are eroding at a high rate. Crop residues properly used, can cut erosion rates in half but over this area as shown by Larson et al. 1976, erosion with present cropping patterns would be in excess of permissible rates even if all crop residues were left on the land. Slopes are moderate throughout this area and much of the land has slopes of 3 percent or less. Erosion or at least offsite erosion, can be controlled relatively easily on this type of land with structures such as terraces and settling basins and such structures must be used if this land is to continue in its present use and erosion reduced to satisfactory levels even without any removal of residues.

Table 2. Relative importance of crop residues for maintaining productivity of soils in Land Resource Region M, the corn belt

Land No.	Use Area Acres x 1000 Total	Corn	Description	Potential for residue use and limit	
102	22,528	5373	Loess, till and sandy prairies Moody	Good	
103	19,169	5741	Central Iowa & Minn. Till Prairies Clarion-Webster	Good	Wind erosion
104	6,238	1863	Eastern Iowa & Minn. Till Prairies Kenyon-Floyd	Good	
105	10,177	1500	Northern Mississippi Valley Loess Hill. Fayette	Moderate	erosion
106	6,097	871	Nebraska and Kansas Loess-drift Hills.	Moderate	erosion
107	11,601	3445	Iowa and Missouri deep loess hills	Moderate	erosion
108	23,721	8032	Illinois & Iowa deep loess and drift	Good	
109	9,665	1220	Iowa & Missouri heavy till plain	Moderate	heavy subsoils & steep slopes
110	5,514	1513	Northern Illinois & Indiana heavy till plain	Moderately good	
111	21,587	5068	Indiana & Ohio till plain	Moderately poor	Forested (Low clay)
112	14,637	590	Cherokee prairie	Poor	Clay pan (Low surface clay)
113	6,015	820	Central clay pan area	Poor	Clay pan
114	11,316	1808	Southern Illinois and Indiana thin loess and till plain	Poor	Clay pan
115	15,313	1875	Central Mississippi Valley, Wooded slopes	Poor	Steep, slopes, forested soils

Certainly not all corn fields should be or could be used each year and probably no one field should be used every year but a reasonable goal might be to use the residue from one half of the fields in this area half of the time.

The 37 million acres with moderate potential includes a variety of soil conditions that limit the suitability of the areas for furnishing corn residues. LRA Nos. 105, 106 and 107 contain large areas of steep slopes where some crop residues are needed to prevent gross erosion between terraces and to achieve a more uniform water intake of the soil than would occur if all residue was removed. LRA No. 108 contains areas of highly productive ridge land (about 20 percent of the total) but large areas of moderately productive and highly erosive till derived hilly soils. These hillsides should not be used for cropland and if they are so used, they need all the crop residues they produce to help keep erosion under control.

LRA No. 111 is a large and agriculturally very important and productive area. A portion of the soils in this area developed under forest, are low in clay in the surface and require regular additions of residues to keep the soils in a good state of tilth. Also there is more use of the corn forage for silage or fodder for livestock feed than in the areas further west. Large quantities of residues are produced and locally adequate quantities might be available but the supply would be less reliable than in the areas previously discussed.

LRA Nos. 112, 113 and 114 are considered to be poor potential sources of residues because most of the cropland in these areas is on nearly level clay-pan soils. These soils developed under prairie but are highly weathered and the surface soils are acid, low in clay and low in organic matter. These soil properties are characteristic of the forested soils to the east where the crop residues are needed on the land to maintain soil productivity.

LRA No. 115 is dominated by steep sloped and forested soils. The area is not well suited to crop production and on most cropland the residues that are produced are needed and are used on the land.

Summary of potentials for use of crop residues for energy generation

The principal source of crop residue that could be removed from the land without seriously lowering future crop production or greatly raising production costs is the corn residue that is commonly left on the fields throughout much of the corn belt. The desirable physical conditions of many of the Mollisols and Entisols of this region, the soils that developed under tall grass prairie depend more on the amount and kind of clays in the surface than on organic matter and the nature of the clays is not easily changed by man. Sloping land in this region is subject to erosion but about 80 million acres are on slopes of less than 3 percent where water erosion can be readily controlled and the land remain in row crops. The 50 million or so acres of cropland in this region that is on sloping land is subject to severe erosion if used for clean tilled crops such as corn and soybeans. Erosion can be controlled in part by minimum tillage practices and by interseeding and off site erosion damage can be controlled with terraces and settling basins on most.

In this region some 35-45 million acres are in corn each year furnishing a large potential source of corn stover within about 200 miles of the Illinois-Iowa border as at Davenport-Moline.

Another source of energy from crop residues is from wheat straw and in good crop years a ton or so per acre might be garnered from the wheat fields of the plains states, but mostly in Kansas. In dry years, most of the straw would be needed to furnish ground cover. Wheat grown in a double cropping system with soybeans in the southeastern United States furnishes a small but fairly dependable source of straw as the straw needs to be removed from the

Summary

Rating	Areas	Acres	Acres of corn	Potential residue Tons/A	Total
				Corn	Tons
Good	102,103 104,108	71,658,000	21,059,000	.75	15.8M
Moderately Good	110	5,514,000	1,513,000	.6	.9M
Moderate	105,106, 107,109	37,540,000	7,036,000	.5	3.5M
Moderately poor	111	21,587,000	5,068,000	.4	2.0M
Poor	112, 113 114, 115	47,281,000	5,093,000	.25	1.3M
		183,580,000	39,769,000		23.5

land before soybeans are planted.

Rice straw, though high in silica, might supplement wheat straw from the wheat-soybean double crop fields in the delta in LRR, O.

No mention has been made of the use of oat straw or of hay crops for energy generation because in general, these crops are produced only as needed in livestock operations and all oat straw is used for bedding or feed.

Growth of Crops Primarily for Energy Production

There are two major areas on which plant growth primarily for energy production should logically be considered: 1) on soils unsuited to food production in humid sections because of steep slopes, shallow, rocky or otherwise unsuitable soils for crop production and 2) in arid and semi-arid regions where food crops or forage makes scant growth.

In the humid regions emphasis would logically be on production of calories and a wide array of annual and perennial plants warrant consideration. In most instances, costs would dictate that the terrain be accessible to harvest equipment and costs also would usually favor perennials. Such perennials as Johnson grass, if heavily fertilized with N, can produce 6 to 10 tons of dry matter per acre per year. Hybrid popular, kudzu, and crotolaria are examples of the range of plant species that either are extensive now or could be introduced and harvested on a sustained basis for power generation.

With the perennials, a mat of living roots would be present at all times and with most species the soil surface would be protected even following harvest so erosion should be easily controlled under most systems. Soil deterioration problems would be mostly confined to fertility declines which could be corrected with fertilizers.

If the assumption is made that no land in humid sections would be taken out of cropland for this use, competition for land would be between land for pasture or forest and on the forest land the competition would be between wood for pulp or lumber or for energy.

There is a vast total potential acreage in this category. As shown in Table 3 there are in the private sector 102,444,000 acres of pasture, 462,724,000 acres of forest and 380,311,000 acres of range land. Climatic conditions on pastureland and forest are generally humid but range from sub-humid and semi-arid on the rangeland.

Nationally there is a large reservoir of LUC Classes I through III that is not now in cropland amounting to some 230 million acres. The largest concentration of this quality of land is in the southeastern coastal plains in Land Resource Region P where there is some 50 million acres of land in this category. This land is now in pasture or forest and some would require drainage before it could be used for cropland but might be suitable in its present state for production of some types of energy crops. Production of plant growth for energy uses would, of course, be in conflict with their use for forest or pasture and potentially for their use as cropland.

In the arid and semi-arid regions, total vegetative growth is much less than in humid regions. Over vast areas total annual growth is sufficient only to support one cow on 20 to 40 acres of range.

On such areas, interest is less in total production than in production of specialized compounds such as are commonly produced by special species under conditions of drought stress. Production of rubber by the quayale plant is such an example. Some plants of semi-arid regions produce a hydro-carbon compound that can readily be converted into a gasoline-like fuel.

Table 3. Major Land Use Categories in the United States*

	1,000 acres	% Non Federal Rural	% Total
Total Land Area	2,268,215		100
Non Federal Rural Land	1,440,002	100	64
Cropland	437,583	30	19
Pastureland	102,444	7	5
Rangeland	380,311	26	17
Forest land	462,724	32	20
Other	56,302	4	3
		Federal, Urban Etc.	
All other lands	827,838	100	36
Federal Noncropland	759,602**	92	33
Urban and built-up	61,119	7	3
Water area	7,117	1	-

*From National Inventory of Soil and Water Conservation Needs 1967, USDA, Stat B. No. 461.

**Of the Federal noncropland 360,035,000 acres or 43 percent of total is in Alaska.

Production of total calories per acre per year would be small under desert conditions but production of special photosynthates could be very important. There are many acres of dry land that are now producing very low yields of any useful product. Special plant species that could accumulate hydrocarbons for several years might reduce plant establishment and harvesting costs to a practical point. These desert areas could not compete with humid areas in terms of total calories produced but might well become valuable sources of special fuels.

There does not appear to be any reason for concern for soil deterioration under any conceivable type of special plant production program on desert and semi-desert lands.

Large areas of the dry lands are public lands included in the 759,602,000 acres of Federal noncropland category of Table 3. Portions of the 380,311,000 acres of rangeland listed as nonfederal rural land also is of this nature.

Appendix A

Major Land Use Divisions in the United States

As shown in Table 3 there are 438,240,000 acres of cropland shown in the 1967 National Investory of Soil and Water Conservation needs on nonfederal rural land in the United States. This cropland is about 20 percent of the total land area.

As shown in Table 4 most cropland is on LUC (Land Use Capability Classes) Classes I to III. Ninety percent of all row crops are on LUC I and III and as yields are higher on these soils than on the other LU Classes, essentially all row crop production takes place on these soils.

Table 5 includes a classification of cropland by LU Classes and sub-classes for 16 midwest states, which includes the corn belt. This table shows that on 158.8 million acres of cropland out of a total of 209.7 million acres in this region, erosion is not the most severe problem.

Table 4. Cropland in the United States by Land Use Capability Classes*

LUC	Cropland 1000 acres	%	Row crops 1000 acres	%	Close grown crops 100 acres	%
I	36,276	8	22,044	14	5,645	6
II	187,258	43	78,585	49	45,128	45
III	141,710	32	44,788	28	35,190	35
I-III-Total	365,243	83	145,417	91	85,964	86
IV	49,740	11	11,199	6	11,121	11
V	2,076	0.5	484	--	191	--
VI	16,325	4	2,591	2	2,981	3
VII	4,105	1	649	-	381	-
VIII	94	-	15	-	6	-
TOTAL	437,583	100	160,355	100	100,644	100

*From National Inventory of Soil and Water Conservation Needs 1967, USDA, Stat B. No. 461.

Table 5. Cropland in the 16 north central states region of the United States by Land Use Capability Class*

State	I	II	IIIWSC	SUBTOTAL	IIIe	TOTAL
	Land Use Capability Class					
	1000 acres					
Kansas	1,284	5,652	1,913	8,849	15,018	23,867
Kentucky	672	2,941	434	4,047	1,114	5,161
Illinois	923	16,410	2,265	19,598	2,199	21,797
Indiana	490	10,340	1,310	12,140	592	12,732
Iowa	2,825	13,067	1,498	17,390	6,451	23,841
Michigan	61	6,148	2,460	8,669	458	9,127
Minnesota	1,511	12,862	3,947	18,320	1,350	19,670
Missouri	1,533	3,588	2,722	7,843	6,039	13,882
Nebraska	1,896	8,105	870	10,871	6,217	17,088
North Dakota	26	14,051	3,456	17,533	7,067	24,600
Ohio	292	8,925	1,227	10,444	1,495	11,939
South Dakota	662	8,941	2,703	12,306	1,372	13,678
Wisconsin	448	8,245	2,075	10,768	1,600	12,368
Totals				158,778	50,980	209,758

*From Shrader and Landgren (4).

References Cited

Anonymous. 1964. Silage. Potash News Letter. No. L-1 35.

Barnhart, Steven L. Effects of corn grain versus whole plant harvest on soil fertility. Master of Science Thesis. Iowa State Univ. 1977.

Bartholomew, W. V., W. D. Shrader and A. J. Englehorn. Nitrogen changes attending various crop rotations on Clarion-Webster soils in Iowa. Agron. Journal V. 49. 1957.

Brady, N. C. 1974. The nature and properties of soils, 8th Ed. Macmillan Pub. Co. Inc., NY.

De Leenheer L. 1958. La degradation de la structure des sols en Belgique et ses causes. Proc. of the International Symposium on Soil Structure. Ghent, Belgium.

Engelstad, O. P., W. D. Shrader and L. C. Dumenil. The Effect of Surface Soil Thickness on Corn Yields: I. As Determined by a Series of Field Experiments in Farmer-operated Fields. II. As determined by an Experiment using Normal Surface Soil and Artifically-exposed Subsoil. Soil Science Soc. of Amer. Vol. 25, No. 6. 1961.

Greenland, D. J. 1975. Bringing the green revolution to the shifting cultivator. Science. 190:841-844.

Klingebiel, A. A. Land Resources Available to People in the United States. Proc. 16th Annual Meeting Agr. Res. Inst. National Research Council, Washington, D. C. 1967.

Larson, W., R. F. Holt and C. W. Carlson. 1976. Residues for resource conservation, soil productivity and environmental protection. Presented at 1976 Annual Meeting of American Society of Agronomy, Houston, Texas. In process of publication.

Mannering, T. V. and L. D. Meyer. 1963. The effect of various rates of surface mulch on infiltration and erosion. Soil Science Society of America Proc. Vol. 27:84-86.

McCalla, T. M. and T. J. Army. 1961. Stubble mulch farming. Adv. in Agronomy 13:125-196.

Morachan, Y. B. 1966. Cumulative Effects of organic residue applications on physical and chemical properties of Marshall silty clay loam. Ph.D. Thesis, Iowa State University.

National Inventory of Soil and Water Conservation Needs. 1967. USDA. Stat. B. No. 461.

Shrader, W. D. and N. E. Landgren. Land use implications of agricultural production potentials. From shifts in land use. Dept. of Agric. Econ. Report No. 33. University of Nebraska, May, 1964.

Sutherland, W. N., W. D. Shrader and J. T. Pesek. 1961. Efficiency of legume residue nitrogen and inorganic nitrogen in corn production. Agron. Journal Vol. 53:339-342.

Wischmeir, W. H., and D. D. Smith. 1965, (reprinted 1972). Predicting rainfall-erosion losses from cropland east of the Rocky Mountains. USDA Handb. No. 282. U.S. Gov't. Printing Office, Washington, D.C. 47 p.

Question: As you go farther north, I understand that the residues get to be a problem and as you get to northern Iowa and southern Minnesota you really want to plow residues under in the fall so that you will have soil warm up quickly in the spring and that encourages erosion.

Answer: That is quite correct. There are no easy answers. In fact, sometimes there are no answers. And this is the case where there are these conflicting objectives and problems. If you control the erosion you increase the disease hazard, you increase the problems of insufficient temperature.

ADDRESS BY

Charles N. Kimball
Chairman, Board of Trustees
Midwest Research Institute

Biomass Energy Conference
Crown Center Hotel
Kansas City, Missouri

March 2, 1977

It is a pleasure to talk with you today. It is also a distinct privilege. Let me also confess at the outset that not too many months ago I wasn't familiar with the term -- Biomass -- or its importance.

When asked to speak to you late last week, I was a bit at loose ends. Clearly, I couldn't discourse on the policy issues that the Secretary of Agriculture would have addressed. What would I say to you; what theme should I key my remarks to? Musing about this, I felt some obligation to speak out on some issues of scientific substance. After all, my entire career of 40+ years has been in research or the management of it. I said to myself, "You should not have been surprised by the new word "Biomass" and you should know a good deal more about it than you do."

I was perplexed as I thought about this. Then it began to occur to me that in my 25 years as president of MRI, and even from the days of my earlier work in radar and television, I had been forced to learn the real meaning of many new terms...like transistors, integrated circuitry, pacemakers, lasers, cyrogenics, agribusiness, birth control pills, herbicides, regional economics, criminalistics, reverse migration, and so on. I'm sure each of you has a similar list.

Some of these new terms are the product of scientific and technological progress, others result from social, economic and political forces.

The old notion that change is an integral and necessary part of the human existence came back to me, to reinforce the fact that the successful management of change is a prerequisite for accomplishing what we human beings want out of life. How do we cope with change, what changes are upcoming, what can we do given what we know, and what else do we need to know to make things come out the way we want or hope for. "Chance favors the prepared mind."

Each of you is here today because you recognize this general proposition and you want more fully to understand what role biomass can play. You are to be congratulated. Human progress is dependent upon people like you who are both sufficiently skilled and farsighted to explore the unconventional.

Had someone told me 35 years ago when I was working on the emerging technology of radar and pulsing circuits and microwaves, that the cultivation and burning of grass would be the subject of an important conference, I would have been amazed. Yet, given the changes which have occured in the intervening years, this conference is at the forefront. It is aimed at dealing with one of the real future issues of consequence.

The energy crisis has been bandied around as a term so much that I almost hate to mention it especially at an energy related conference. But unless you who are investigating the potential of biomass and your colleagues who are similarly exploring the potential of other means of dealing with the generic energy supply issue are successful, our whole way of life -- the construct of our economy and society, is in real jeopardy.

I literally stand before you physically today because others like you earlier perceived problems and looked to unheard of solutions. For some seven years now, I have had a pacemaker implanted in my chest. Had a few M. D. s and electronics engineers not sought out solutions to my particular heart disorder -- the Stokes-Adams syndrome, known for over 100 years -- and gotten together to exchange information, I would not be your speaker today, or anyone else's speaker.

Whether or not you agree with what I have to say to you today, I am grateful to that earlier group of farsighted researchers. I can't say that I am "eternally" grateful, but I can say that they are the recipients of my gratitude for an extended life, due to their sharing of information among different trades. And so are 90,000 other Americans.

This symposium may not save the life of a particular individual, but it may well contribute to the continuance of our society. I again, commend you for being here.

I have spoken of change and the fact that it is an integral part of the scientific, technological, and human process. But, it is easy to lose sight of this. It is more comfortable to be complacent -- to look back on the good old days -- to believe that we have finally reached fulfillment.

Let me cite an example or two. It wasn't too many years ago that John Kenneth Gailbraeth wrote a book entitled "The Affluent Society," in which he set forth the view that Americans had reached a point wherein our problems were ones of dealing with abundance rather than scarcity. At about the same time, a researcher at the Center for the Study of Democratic Institutions in Santa Barbara published a piece which put forth the notion that economics was an obsolete science. Economics, he said, was the science of the allocation of scarce resources. The future, he said would have to deal with the allocation of abundance.

The oil rich states in the Middle East taught us different. They dramatically demonstrated just how dependent our economy and way of life was dependent upon energy. By their withholding and pricing actions, they proved that our seemingly omnipotent economy had an Achilles heel. For the first time in history, inflation and recession went hand in hand. This upset a number of traditional economic theories. After several years, economists are still groping around with this dilemma. The success of the OPEC cartel was not lost upon others. One of the side benefits you obtain from attending this symposium is that for two days you will not have to listen to your wives complain about coffee prices.

Earlier this week, I heard that the United States and Canada had scheduled talks on the establishment of a wheat cartel; the two nations account for something like 80% of all wheat exports. The results of these talks will be quite important to the future of the Midcontinent region, the segment of the United States between the Mississippi River and the Rocky Mountains. Many of us in Kansas City like to think that it is the Capital of the Midcontinent region. If we are not actually the capital, now, we have plans to become so in the not too distant future.

The control of natural resource sources by more advanced, consuming societies was the basis for the Colonial era, which spanned several centuries worldwide. About midway during the Colonial period it even became codified into economic theory. It was called mercantilism.

This exploitation of the natural resources of others wasn't limited to European nations living high off the resources of Asia, Africa, and South America. It occurred here within the United States too.

For decades this Midcontinent part of the country provided many of the natural resources upon which the established Metropolitan areas of the East flourished. In more recent times, the cities of the West Coast similarly enjoyed the fruits of our resources. The result was that this part of the country suffered from an inferiority complex that was as large as our grain production. We were not underdeveloped, but underrecognized. This in turn led to the export of our most precious resource -- our bright, young people. We educated them well and then sent them off to the East and West coasts to contribute to the economic development of those regions.

At first this outflow of people was based in fact -- the necessary jobs were not in this part of the country. Later, the outflow was reinforced by an ethic among the young. Roughly, it was that only the losers stayed in their hometowns: the bright, well-trained young had to migrate to where they believed the action was.

All that has changed, especially in the last 2-3 decades. But as I mentioned earlier, we are remarkably slow to recognize the reversal of trends and respond to them.

For example, by World War I, it should have been apparent to all that the old order was changing -- that the Colonial system was in the process of decay. Then, during World War II, we went through a number of agonies when the Japanese cut us off from our sources of rubber, tin and other natural resources. It therefore, shouldn't have been a surprise to us when the Arabs did what they did with respect to oil, or the Brazilians are now doing with coffee.

During this same period, changes were occuring within the U. S. economy and society. The South was rising again. However, this time, when the recognition of what was happening finally sank in, it was called the Sun Belt. Similar resurgence was taking place in the Midcontinent. Midwest Research Institute is a product of this trend. In 1944 a few farsighted civic leaders in Kansas City recognized that technology coupled with the natural resources of the region was the key to the future. They looked around, discovered that the resources were here, but that the technology had to be imported from the East and West Coasts -- or that the raw material had to be shipped there, contributing to the jam of those sectors.

Thus, MRI was founded. Clearly, we are not solely responsible for the remarkable turnaround this region has experienced, but we have played our part, and we are proud of it. (15000 scienctists and engineers here -- Linda Hall Library)

One of the more recent things we have done is to establish a series of lectures which we call Midcontinent Perspectives. Now in its third year, it entails monthly get-togethers of the local leadership to listen to acknowledged experts -- all from this region, by the way. We examine issues which will affect the course of events in the Midcontinent. We then distribute monographs of these talks and questions and answer exchanges throughout the region -- to 2 or 3 thousand decision makers. In our first year we focused, rather naturally, on the food supply and demand chain. Last year we looked at the energy situation from the private sector view, and its impact on the region. This year we are conducting a series of speculations on various facets of life in our part of the country as they will be in the year 2001.

This series focuses on current and upcoming issues we face here in the Midcontinent, such as agribusiness, telecommunications, cardiovascular diseases, the future of the family, how cities will be governed in 2001. Your seminar today and tomorrow addresses the potential of a particular solution to some of these issues. I am personally pleased to see this. We are closing in on the problems and opportunities from both ends, i.e., issues and solutions.

Dr. Garland Hadley, Director of the Kerr Foundation in Oklahoma City, and a thorough student of the reverse migration phenomenon, quoted from the London Times in the inaugural session of the Midcontinent Perspectives examination of the year 2001. The quote was, "The Tuesday evening meeting of the Clairvoyance Society of Wicksell has been canceled because of unforeseen circumstances."

Garland went on to say that the art of forecasting must be in some disarray, if the clairvoyance society couldn't project events a week in advance. In my remarks I have alluded to forces which were in the works for decades that we failed to recognize and respond to.

For two days you will be looking at the potential of biomass, its role in the overall energy equation, and as a cash crop. I'm not sure where this places us in the spectrum of things we should recognize as issues and solutions. Perhaps we should have held this seminar 10 or 20 years ago. However, given historical perspective, it appears to me that you are substantially in advance of the reaction time man has typically exhibited.

Since stepping up to Chairman of MRI's Board of Trustees two years ago, I have been deeply involved on a personal basis in carving out a development course for Kansas City and the region it serves. MRI, as an institution, remains true to its founding mandate of regional development. This seminar today and tomorrow is quite important to the future of this part of the country.

Some examples of how what you discuss may affect the course of development in the Midcontinent area:

The eastern edge of the region lies among the densest biomass production area of the nation. On the other hand, the western side of the region is characterized by marginal land upon which the cultivation of biomass crops may well be the best long-term utilization of that land.

Currently, the western land is being used for the production of conventional crops. This use is only possible by the use of irrigation and the kind fortunes of nature. By this I mean, when we get normal or above average rainfall, the western area is a viable conventional crop producing area. In times like those we are now experiencing, which approach drouth conditions, we get not wheat or corn, but dust. Further, the underground water resources upon which current irrigation practices are based are being rapidly depleted. I suspect you may conclude that the best use of this land may be something other than the current practices, and that biomass crop production may figure strongly in the future of that part of our region.

- Second, I presume that all of you know that this region is referred to as the "breadbasket of the United States." Additionally, since some 60% of our national wheat crop, for example, is exported, some have termed the region the "breadbasket of the Soviet Union." This brings to the fore the issue of whether we would be better off concentrating on the production of conventional crops for export or whether -- in the face of the energy crunch -- we should devote some portion of this land to biomass production. Whichever decision is reached will have profound implications for the region.

- Third, until recently a large part of the crops raised were used as feeds for animals. Pricing considerations in recent years have given us some pause here. However, this fluctuates back and forth based on short-term factors.

It may be that you will conclude that less land should be devoted to feed production and more to biomass as a cash crop. If you do, it will have profound repercussions on the existing structure of our economy. The existing capital investment in feed lots, grain elevators and so on would be placed in jeopardy. My point is that this symposium is not an "ivory tower" event; what you conclude will be of great significance to this area.

In short, you have a rather grave responsibility not only to the nation, but to this region. Despite the decline in the national birth rate, there will be 30 to 50 million more Americans by the turn of the century. The Midcontinent region is the logical place for many of these people to live. We retain here a quality of life which is appreciably superior to New York with its problems, or Los Angeles with its problems.

Kansas City on the other hand is still manageable. We have problems but we have many assets. It is still not too late for us to cope. Des Moines, Omaha, Oklahoma City, Minneapolis, Denver, and smaller cities in the Midcontinent are similarly blessed and manufacturing and service business recognize this fact. People do too; they have been voting with their feet by moving back to this part of the country to obtain the life styles they want for themselves and their children and to take advantage of its centrality and open society.

We here want to ensure that the reasons they move back are maintained and enhanced. You at this seminar have a role to play in this scheme of things. Just how we handle the biomass issue, how we balance it off against exports or feed grains will be quite important.

You have a responsibility to both. Today and tomorrow you must as councilman McSheehan, of San Francisco, remonstrated his colleagues in the early 1900s, "Grab the bull by the tail and look the issue squarely in the face."

############

BIOMASS POTENTIAL FROM AGRICULTURAL PRODUCTION

W. R. Benson

Midwest Research Institute

Estimates of the potential quantity of biomass from agricultural production of grain and grass crops have been developed from the analysis of a specially constructed data base.

The inventory of land contained in the data base used for the analysis is based on the Conservation Needs Inventory of 1967. Crop production figures for the years 1971, 1972, and 1973 provided by individual states are averaged for those 3 years.

For some states, however, the information was not readily available, so, the 1967 census of agriculture was used.

The estimates of currently available biomass are derived using current cultural practices as reflected in current crop production figures.

The basis for our data is a county-by-county inventory of crops and also a county-by-county inventory of land-use patterns. However, to present our analysis results on the basis of the more than 3,000 counties in the United States would be somewhat voluminous, and therefore, the land resource area is used as the unit for reporting. Figure 1 depicts the land resource areas of the United States as modified to conform with county boundaries, as used in this analysis.

One of the first questions to be answered was, what is the current production of biomass in the United States from grain and grass sources. Based on the data in our data base, there are approximately 1,228,000,000 tons of biomass from all grains and grass resources in the United States, as shown in Figure 2.

The food consumption of those grains and grasses comprises 19.4% of the total and is equivalent to about 239 million tons. The grain and grass type crops which are included in this study are planted on 206 million acres.

The residue component of food crops comprises 24.4% of the total biomass and it similarly is planted on those same 206 million acres with a total yield of 299 million tons. Forages are planted on 49 million acres contributing 9.9% of the total biomass, or a total of 122 million tons.

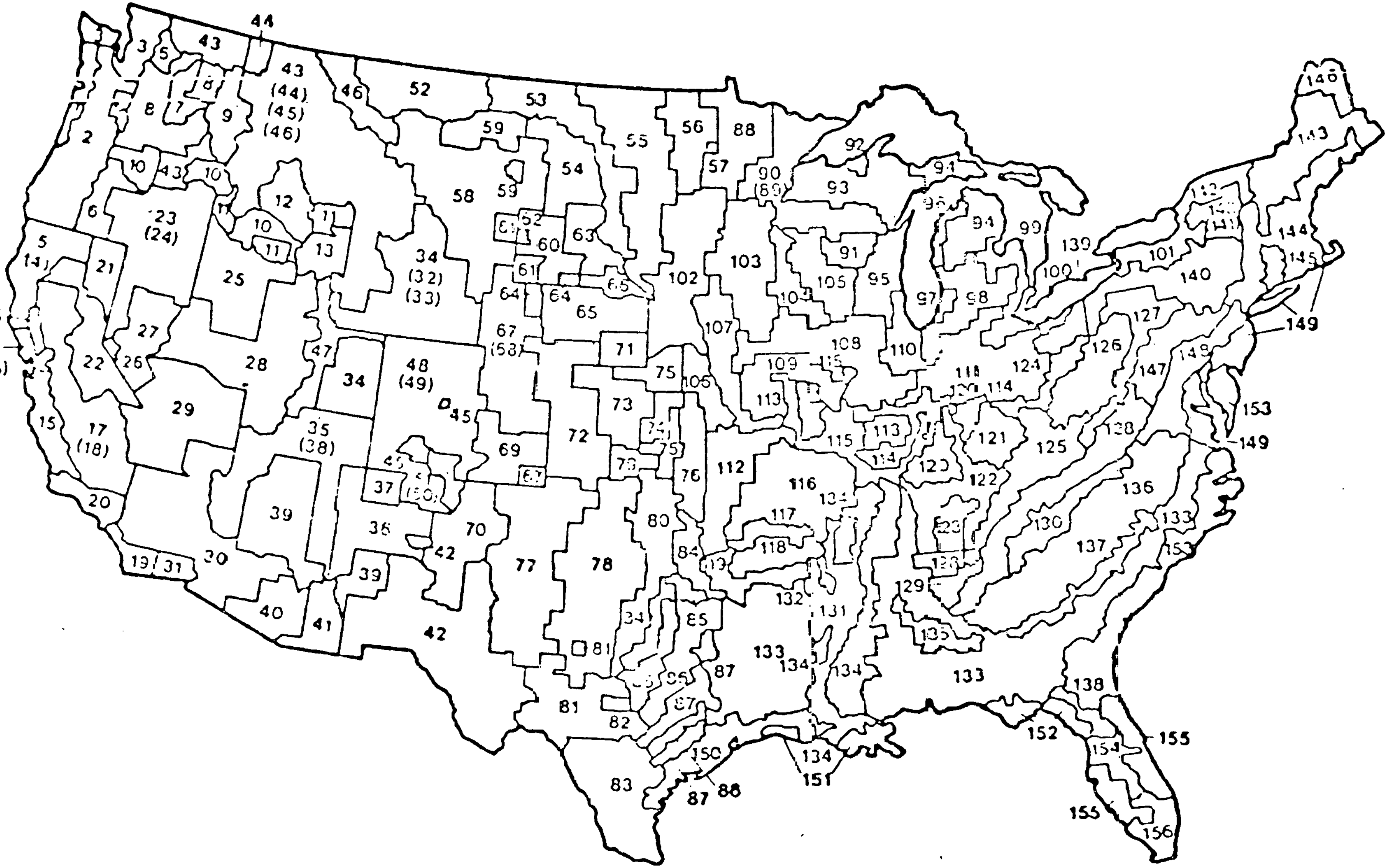

44
3
5
43
43
(44)
(45)
(46)
46
52
53
8
8
7
9
2
55
56
88
59
92
146
143
57
90
(89)
93
94
10
43
10
12
58
59
54
6
123
(24)
11
10
11
13
34
(32)
(33)
52
60
63
91
95
96
94
99
139
101
5
(4)
21
25
61
64
64
65
65
102
103
105
104
97
98
100
140
144
145
15
14
(16)
27
22
26
28
47
34
48
(49)
45
67
(68)
71
75
106
107
108
109
110
111
114
124
126
127
147
148
149
29
15
17
(18)
35
(38)
69
72
73
74
75
113
115
113
114
120
121
125
128
153
149
20
39
37
36
70
76
78
112
116
117
118
122
123
136
130
133
137
19
31
30
42
77
80
84
119
132
131
129
126
135
40
41
39
42
81
85
87
133
134
134
133
138
82
86
87
150
83
87
88
134
151
152
154
155
155
156

Figure 1

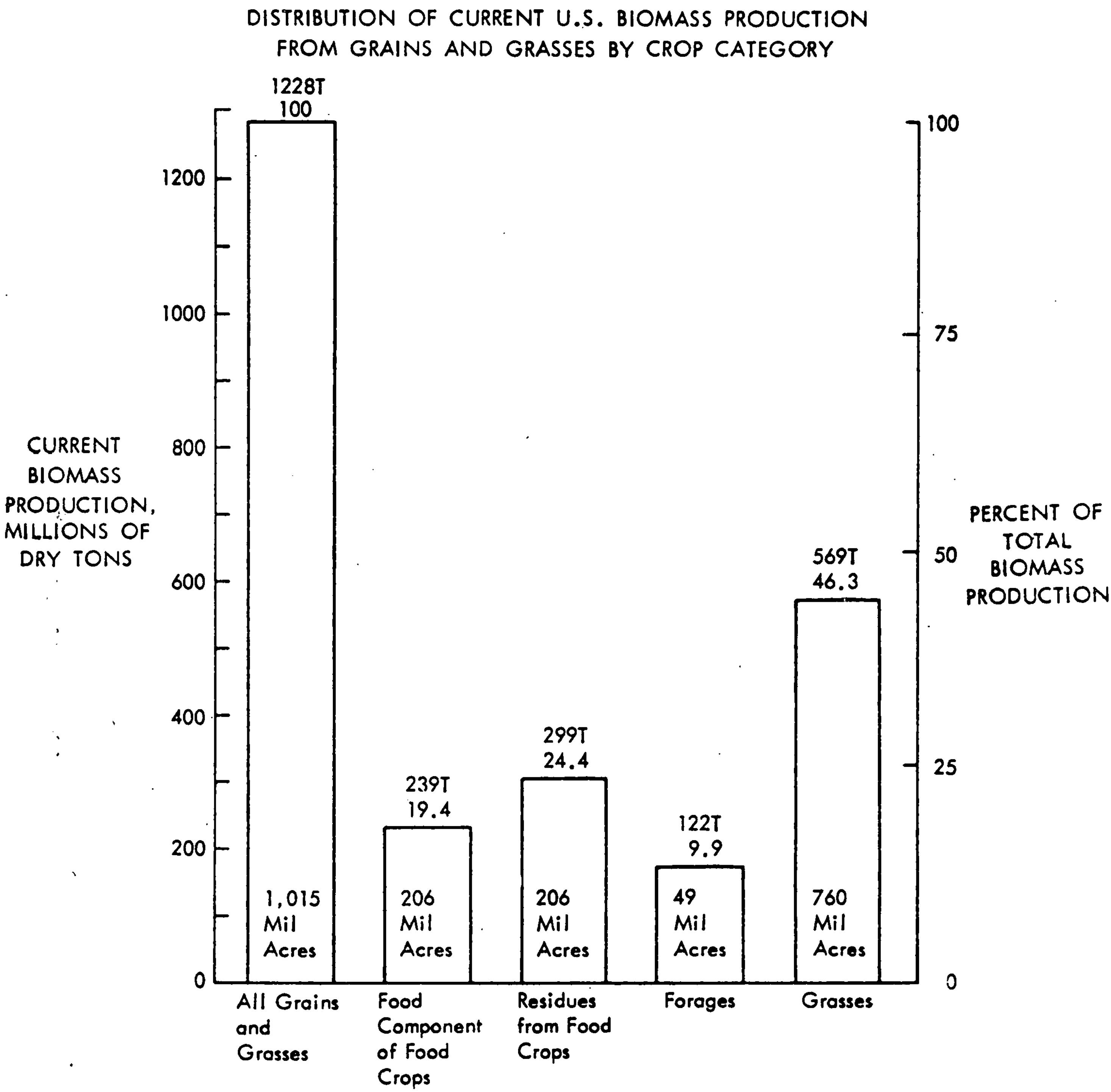

DISTRIBUTION OF CURRENT U.S. BIOMASS PRODUCTION
FROM GRAINS AND GRASSES BY CROP CATEGORY
CURRENT BIOMASS PRODUCTION, MILLIONS OF DRY TONS
PERCENT OF TOTAL BIOMASS PRODUCTION
0
200
400
600
800
1000
1200
0
25
50
75
100
1228T
100
1,015 Mil Acres
239T
19.4
206 Mil Acres
299T
24.4
206 Mil Acres
122T
9.9
49 Mil Acres
569T
46.3
760 Mil Acres
All Grains and Grasses
Food Component of Food Crops
Residues from Food Crops
Forages
Grasses

Figure 2

The largest contribution to total biomass yield is from the grasses. A 46.3% of all the biomass from grain and grass sources is in the form of pasture and range grass. It is planted on 760 million acres. This area includes the land reported in the Conservation Needs Inventory as land in pasture and land in range grass and also a figure derived by MRI which represents federal rangeland. It is inappropriate to exclude this very large expanse of land which was not included in the Conservation Needs Inventory. We developed a method for deriving the federal rangelands mathematically from the Conservation Needs Inventory and other data indicating the area of each individual county. The land-use patterns and land capability classes for federal rangeland are assumed to have the same distribution as for other rangeland within the same county. If there was no rangeland in a given county, an adjacent county or adjacent LRA was used to derive the distribution.

The analytical program for performing these analyses were developed by Dr. Michael Davis of our staff. The format for presenting the analysis results also provides for displaying the parameters of the particular analysis. Figure 3 shows the total biomass available from crop residues, forages and grasses.

Note that the report displays the land resource areas rank ordered and in this case on column 10, the average yield in tons per acre for the particular land resource area. Figure 3 is the first page of a multi-page report; all 156 land resource areas appear in appropriate rank order on subsequent pages. The bottom line of the report shows totals for the entire United States and the subtotal shows cumulative values.

Note that the highest average biomass yield per acre is only 2.2 tons per acre, quite different from the 5 to 20 ton per acre yields anticipated from underexploited species.

Four types of crops, are provided for in the analysis: food crops, forage crops, grass crops and new crops. The food crops that are included are Texas corn, corn, wheat, barley, rye, oats, sorghum grain, soybeams, rice straw, hops, sunflower, safflower, and peanut hay.

The forage crops included are: corn silage, corn green chop, sorghum silage, sorghum hay, sorghum grazed, alfalfa hay, clover, timothy and mixtures, small grain hay, other hay, grass silage, and green chop hay. The grasses included pasture grass, range grass and federal range grass. The five new crops that are also part of the data base include kenaf, giant reed, cattails, guayule, and guayule/mariola.

It is of interest to examine each of these components individually. Current residues from food crops analysis is shown in Figure 4. Note that the highest residue density is 2.4 tons per acre. That figure is the average for all crops grown in the particular land resource area. This is not

ESTIMATED ANNUAL BIOMASS PRODUCTION FROM GRAINS AND GRASSES
FOR LAND RESOURCE AREAS (LRA), RANK ORDERED ON COLUMN 10 OF THIS REPORT

SCENARIO TITLE: CURRENT RESIDUES, FORAGES AND GRASSES

FOOD CROPS INCLUDED: TCOR CORN WHEA BARL RYE OATS SORG SOY RICS HOPS SUNF SAF PEAH
LAND TYPES: TCOR CORN WHEA BARL RYE OATS SORG
SOY RICS HOPS SUNF SAF PEAH
FORAGE CROPS INCLUDED: CORS CORG SORS SORH SRGG ALFA CLOV SMAL OTHR GRSS GREN
LAND TYPES: CORS CORG SORS SORH SRGG ALFA CLOV
SMAL OTHR GRSS GREN
GRASS CROPS INCLUDED: PAST RNGE FRNG
LAND TYPES: PAST RNGE FRNG

NEW CROPS INCLUDED:
LAND TYPES:

(AREAS ARE IN THOUSANDS OF ACRES AND YIELDS ARE IN THOUSANDS OF AIR-DRIED TONS)

1 LRA NO.	2 TOTAL AREA	3 FOOD CROP TOTAL YIELD	4 FOOD CROP RESIDUE YIELD	5 FORAGE CROP YIELD	6 GRASS CROP YIELD	7 NEW CROP YIELD	8 TOTAL BIOMASS YIELD	9 BIOMASS PRODUCTION AREA	10 AVERAGE BIOMASS PRODUCTION TONS/ACRE
95	9069.	0.	4805.	4525.	1781.	0.	11111.	4973.	2.2
108	23721.	0.	31953.	2971.	4496.	0.	39421.	18123.	2.2
110	5514.	0.	6671.	456.	917.	0.	8044.	3734.	2.2
104	6238.	0.	6795.	1628.	1025.	0.	9449.	4567.	2.1
105	10177.	0.	4781.	4098.	2706.	0.	11585.	5604.	2.1
103	19169.	0.	22071.	3806.	2264.	0.	28141.	14425.	2.0
98	11311.	0.	5207.	1956.	2495.	0.	9658.	4999.	1.9
107	11601.	0.	11956.	2297.	2396.	0.	16649.	8669.	1.9
96	2003.	0.	63.	111.	371.	0.	545.	295.	1.9
111	21587.	0.	19940.	2592.	4625.	0.	27156.	14917.	1.8
139	3801.	0.	823.	683.	1095.	0.	2601.	1484.	1.8
SUBTOTAL	124191.	0.	115066.	25123.	24171.	0.	164360.	81790.	
TOTALS	1895418.	0.	299260.	121721.	568704.	0.	989689.	1012748.	

Figure 3

ESTIMATED ANNUAL BIOMASS PRODUCTION FROM GRAINS AND GRASSES
FOR LAND RESOURCE AREAS (LRA), RANK ORDERED ON COLUMN 10 OF THIS REPORT

SCENARIO TITLE: CURRENT RESIDUES

FOOD CROPS INCLUDED: TCOR CORN WHEA BARL RYE OATS SORG SOY RICS HOPS SUNF SAF PEAH
LAND TYPES: TCOR CORN WHEA BARL RYE OATS SORG SOY RICS HOPS SUNF SAF PEAH
FORAGE CROPS INCLUDED:
LAND TYPES:

GRASS CROPS INCLUDED:
LAND TYPES:

NEW CROPS INCLUDED:
LAND TYPES:

(AREAS ARE IN THOUSANDS OF ACRES AND YIELDS ARE IN THOUSANDS OF AIR-DRIED TONS)

1 LRA NO.	2 TOTAL AREA	3 FOOD CROP TOTAL YIELD	4 FOOD CROP RESIDUE YIELD	5 FORAGE CROP YIELD	6 GRASS CROP YIELD	7 NEW CROP YIELD	8 TOTAL BIOMASS YIELD	9 BIOMASS PRODUCTION AREA	10 AVERAGE BIOMASS PRODUCTION TONS/ACRE
71	4665.	0.	2179.	0.	0.	0.	2179.	896.	2.4
108	23721.	0.	31953.	0.	0.	0.	31953.	13964.	2.3
110	5514.	0.	6671.	0.	0.	0.	6671.	2942.	2.3
31	2714.	0.	347.	0.	0.	0.	347.	155.	2.2
41	7757.	0.	278.	0.	0.	0.	278.	125.	2.2
105	10177.	0.	4781.	0.	0.	0.	4781.	2247.	2.1
107	11601.	0.	11956.	0.	0.	0.	11956.	5629.	2.1
14	2356.	0.	181.	0.	0.	0.	181.	87.	2.1
104	6238.	0.	6795.	0.	0.	0.	6795.	3312.	2.1
95	9069.	0.	4805.	0.	0.	0.	4805.	2394.	2.0
103	19169.	0.	22071.	0.	0.	0.	22071.	11247.	2.0
SUBTOTAL	102982.	0.	92018.	0.	0.	0.	92018.	42999.	
TOTALS	1895418.	0.	299260.	0.	0.	0.	299260.	202843.	

Figure 4

to say that there are not higher yields within a given LRA. The density of biomass yield is an indirect measure of the economics of collection and the availability of biomass sources within that land resource area.

The geographic distribution of biomass is shown in Figure 5.* The higher densities are in the corn belt and the California valley region.

The analysis for biomass from forages shows much higher yield densities for the forages than for residues with yields running up to averages of 6 tons per acre, see Figure 6. Of course, the total yields are much smaller than for residues because fewer acres are planted. The geographic distribution of forage yield densities are shown in Figure 7.* Many of these forages are produced under conditions of irrigation.

The analysis for biomass from grasses is shown in Figure 8. Note that the yield densities of grasses are very low. The best LRA's yield less than 2 tons per acre. The average yield for the entire United States is approximately 3/4 ton per acre.

Data are not readily available for yields of grasses; yields for grasses were derived. The COA yield for "other hay" on crop land in each county was reduced by 0.25 for pastureland and by 0.5, for rangeland and entered into the data base as the projected yield for biomass from grass sources.

The geographic distribution of grass is shown on the map of Figure 9.* Those LRA's in which the average biomass density is 1-1/2 tons per acre or greater are of particular interest. With this density in contiguous acres, a collection radius of 10 miles would be required to support a 41 megawatt power plant fired with 100% biomass fuel, assuming a heat value for the biomass of 16 million Btu's per ton, and a heat rate for the plant of 13,500 Btu/kw-hr.

The contribution the residue of various food crops to the biomass yield is shown in Figure 10. The width of the bar shows the relative density of average residue yield, and the height reflects the total number of acres planted. Therefore, the area of each bar of the histogram shows the contribution of that crop to total biomass based on current production figures. Note that corn makes the major contribution with 156 tons of biomass material planted in 61 million acres. Wheat and soybeans, are the next two major contribution crops, with sorghum, oats and barley and others making lesser contributions.

The figures at the top of each bar show the range of average densities by LRA which were determined by the analysis.

* Figures 5, 7, and 9 not included.

ESTIMATED ANNUAL BIOMASS PRODUCTION FROM GRAINS AND GRASSES
FOR LAND RESOURCE AREAS (LRA), RANK ORDERED ON COLUMN 10 OF THIS REPORT

SCENARIO TITLE: CURRENT FORAGES

FOOD CROPS INCLUDED:
LAND TYPES:

FORAGE CROPS INCLUDED: CORS CORG SORS SORH SRGG ALFA CLOV SMAL OTHR GRSS GREN
LAND TYPES: CORS CORG SORS SORH SRGG ALFA CLOV
SMAL OTHR GRSS GREN

GRASS CROPS INCLUDED:
LAND TYPES:

NEW CROPS INCLUDED:
LAND TYPES:

(AREAS ARE IN THOUSANDS OF ACRES AND YIELDS ARE IN THOUSANDS OF AIR-DRIED TONS)

1 LRA NO.	2 TOTAL AREA	3 FOOD CROP TOTAL YIELD	4 FOOD CROP RESIDUE YIELD	5 FORAGE CROP YIELD	6 GRASS CROP YIELD	7 NEW CROP YIELD	8 TOTAL BIOMASS YIELD	9 BIOMASS PRODUCTION AREA	10 AVERAGE BIOMASS PRODUCTION TONS/ACRE
31	2714.	0.	0.	801.	0.	C.	801.	134.	6.0
30	34755.	0.	0.	820.	0.	C.	820.	152.	5.4
7	3524.	0.	0.	161.	0.	0.	161.	31.	5.3
17	24122.	0.	0.	3643.	0.	0.	3643.	694.	5.2
20	5548.	0.	0.	334.	0.	0.	334.	65.	5.1
41	7757.	0.	0.	51.	0.	0.	51.	10.	4.9
42	49717.	0.	0.	562.	0.	0.	562.	114.	4.9
40	9147.	0.	0.	136.	0.	0.	136.	28.	4.8
37	3520.	0.	0.	31.	0.	0.	31.	8.	3.9
11	6719.	0.	0.	1126.	0.	0.	1126.	288.	3.9
27	10829.	0.	0.	286.	0.	0.	286.	76.	3.8
SUBTOTAL	158653.	0.	0.	7952.	0.	0.	7952.	1602.	
TOTALS	1895418.	0.	0.	121721.	0.	0.	121721.	50074.	

Figure 6

ESTIMATED ANNUAL BIOMASS PRODUCTION FROM GRAINS AND GRASSES
FOR LAND RESOURCE AREAS (LRA), RANK ORDERED ON COLUMN 10 OF THIS REPORT

SCENARIO TITLE: CURRENT GRASSES

FOOD CROPS INCLUDED:
LAND TYPES:

FORAGE CROPS INCLUDED:
LAND TYPES:

GRASS CROPS INCLUDED: PAST RNGE FRNG
LAND TYPES: PAST RNGE FRNG

NEW CROPS INCLUDED:
LAND TYPES:

(AREAS ARE IN THOUSANDS OF ACRES AND YIELDS ARE IN THOUSANDS OF AIR-DRIED TONS)

1 LRA NO.	2 TOTAL AREA	3 FOOD CROP TOTAL YIELD	4 FOOD CROP RESIDUE YIELD	5 FORAGE CROP YIELD	6 GRASS CROP YIELD	7 NEW CROP YIELD	8 TOTAL BIOMASS YIELD	9 BIOMASS PRODUCTION AREA	10 AVERAGE BIOMASS PRODUCTION TONS/ACRE
152	4264.	0.	0.	0.	413.	0.	413.	234.	1.8
96	2003.	0.	0.	0.	371.	0.	371.	210.	1.8
137	6086.	0.	0.	0.	906.	0.	906.	517.	1.8
155	9702.	0.	0.	0.	4329.	0.	4329.	2496.	1.7
98	11311.	0.	0.	0.	2495.	0.	2495.	1498.	1.7
138	2721.	0.	0.	0.	794.	0.	794.	482.	1.6
100	925.	0.	0.	0.	362.	0.	362.	225.	1.6
95	9069.	0.	0.	0.	1781.	0.	1781.	1172.	1.5
153	26269.	0.	0.	0.	2116.	0.	2116.	1406.	1.5
111	21587.	0.	0.	0.	4625.	0.	4625.	3085.	1.5
139	3801.	0.	0.	0.	1095.	0.	1095.	744.	1.5
SUBTOTAL	97737.	0.	0.	0.	19288.	0.	19288.	12070.	
TOTALS	1895418.	0.	0.	0.	568704.	0.	568704.	759828.	

Figure 8

CURRENT U.S. GRAIN FOOD CROP RESIDUE YIELDS

Figure 10

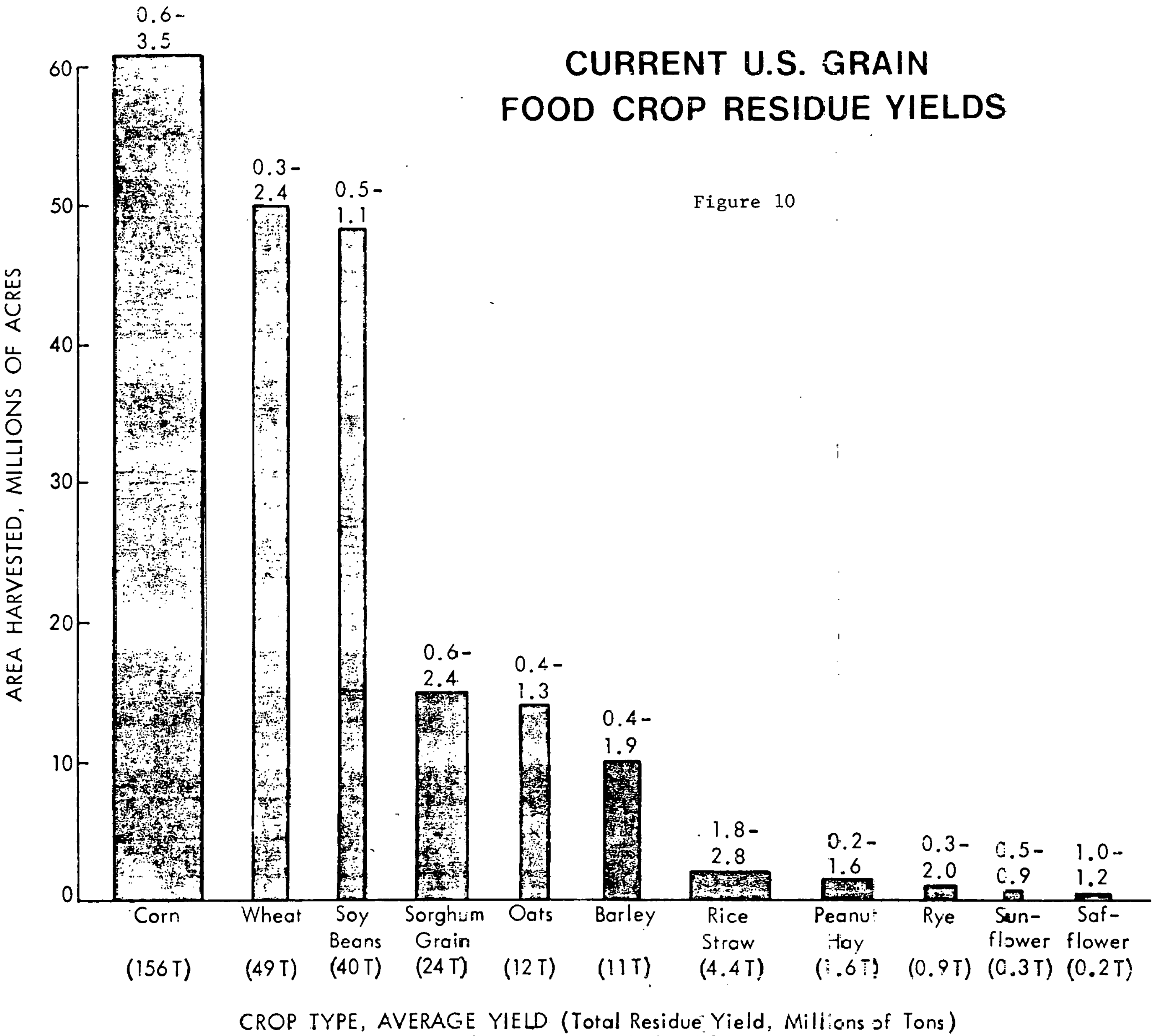


Figure 11 shows current U.S. forage crop yields. Note that only 49 million acres are planted in forages for the entire United States. The yields for forages are considerably greater than for crop residues, with some yields being nearly 10 tons per acre.

Because of problems of erosion control, not all residue can be removed from the land. In recognition of this problem we applied an 80% factor to the indicated yields of food crops for the next analysis, shown in Figure 12, entitled residues and spoiled forages. In this analysis 80% of the residues are included. Approximately 10% of the forages produced are spoiled and, therefore, unsuitable for use as feed, and are included in this analysis as biomass. Grass crop yields are not included in this analysis, due to the low density of grass crops, and the likely high cost of harvesting of grass. It may be that grass has a high potential for contributing large quantities of biomass, given that it can be economically harevested.

If crops with higher yields could be planted on these grasslands; the economics of harvesting and collecting a biomass might be more favorable. In this next analysis 10% of the rangeland is planted in new crops. The new crops included are kenaf, giant reed, cattail, guayule, and a hybrid of guayule with mariola. The land, however, is assigned by land capability class land use category combinations as shown in Figure 13.

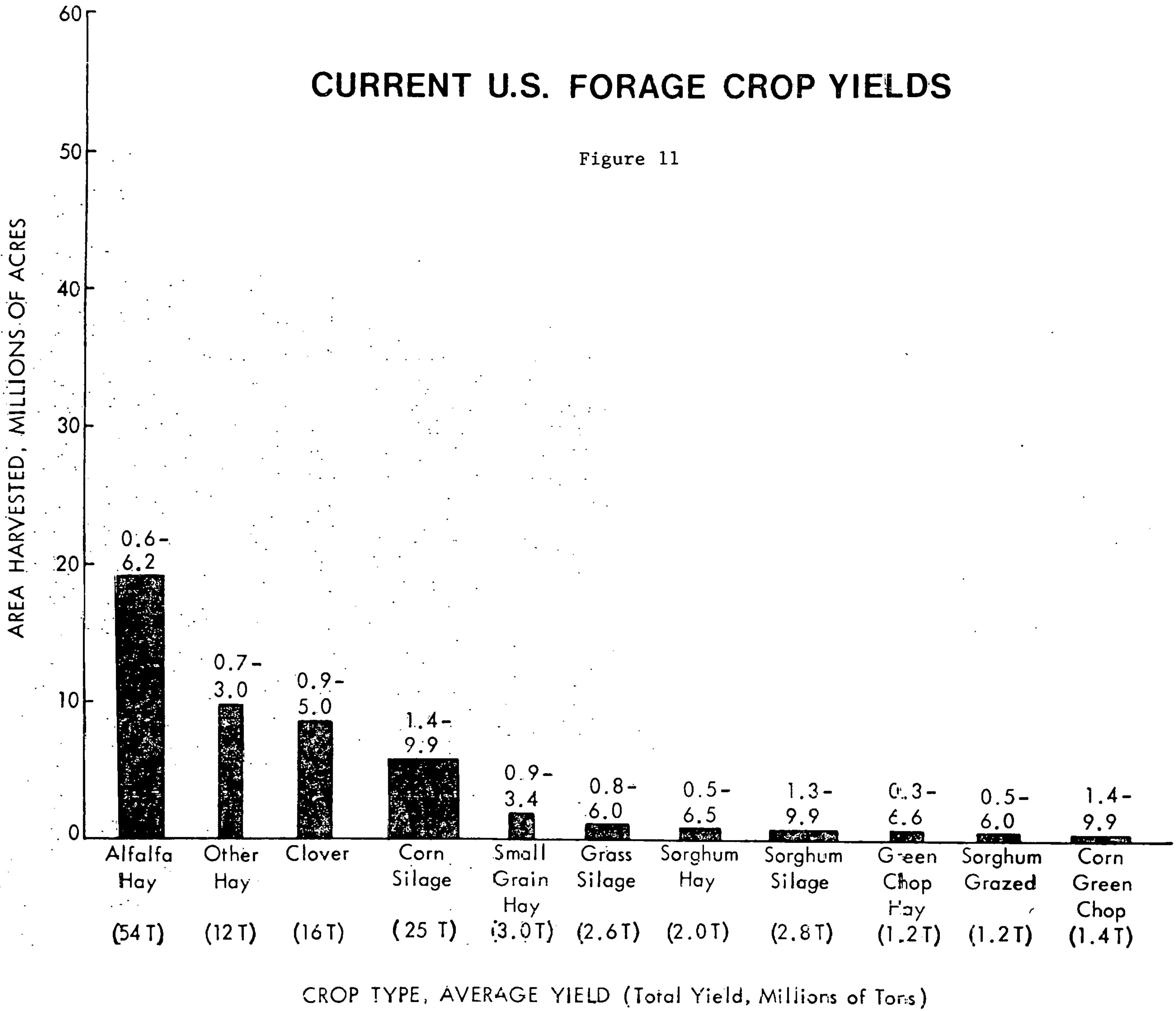
Each new crop is planted in those LRA's where it can be adapted. The total biomass production for this analysis is shown in column 8 as 484 million tons. The analysis results are shown graphically in Figure 14.

Another scenario was developed which assumed a different feeding regimen for cattle such that they would be fed a longer period on grass. This concept would reduce the number of acres that are devoted to producing grain to feed cattle, opening the possibility of converting those acres to the production of biomass. In one such scenario no grain is fed to cattle under 700 lb. The vacated croplands are planted in the highest yield crop for each LRA. This biomass is combined with the reamining crop residues, spoiled forages, and new crops on 10% of the marginal lands. This scenario has a biomass yield potential of 523 million air dry tons, distributed as shown in Figure 15.

The next scenario, considered is to reduce the grain fed to cattle to only those under 900 lb. It provided a further reduction on the amount of grain fed to cattle and an additional vacation of cropland to be planted in a high yield crop. The analysis program selected the crop having the highest yield for each LRA and planted it on the croplands vacated in the LRA. This scenario is a potential yield of 569 million tons. See Figure 16.

CURRENT U.S. FORAGE CROP YIELDS

Figure 11



BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: RESIDUES AND SPOILED FORAGES

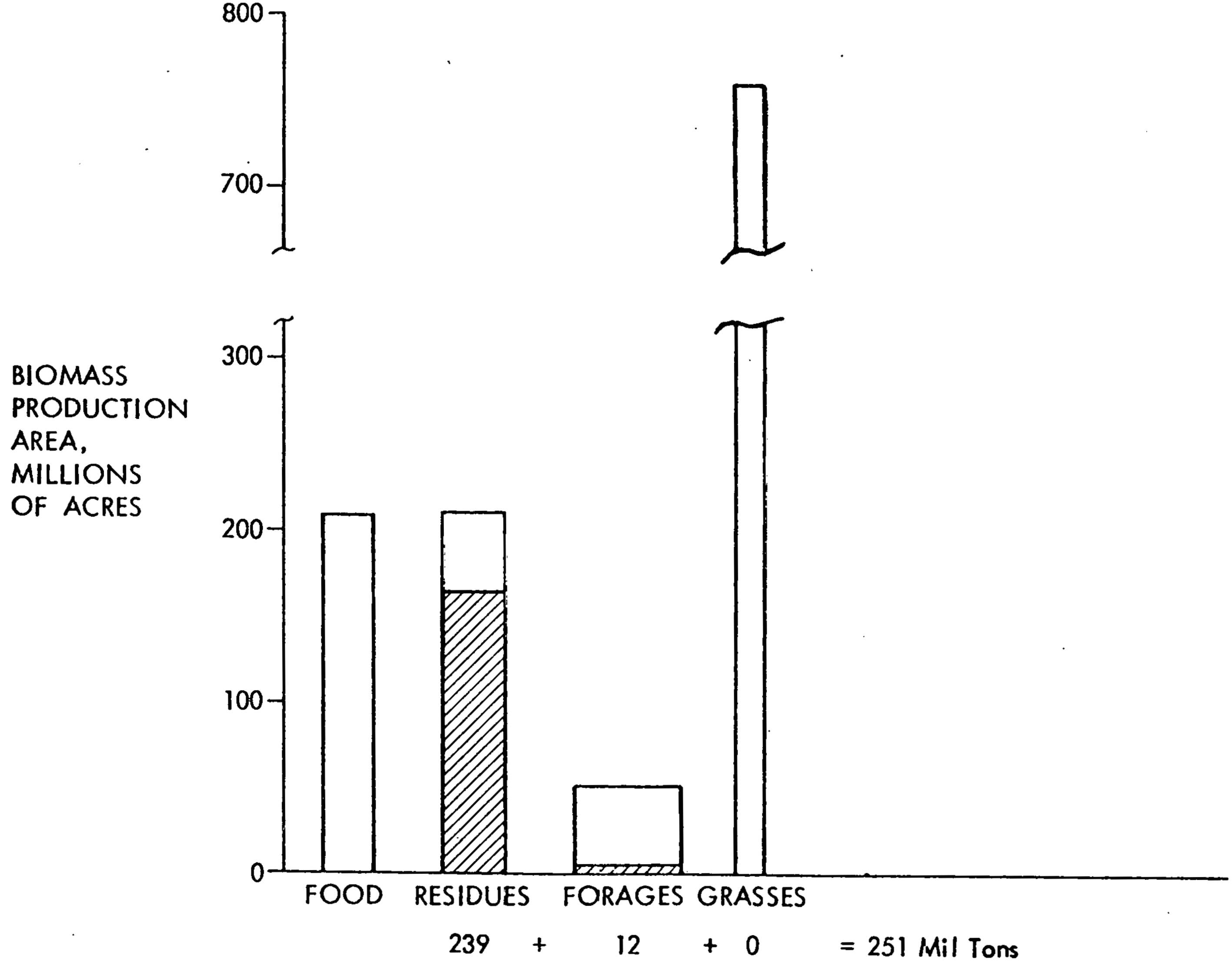


Figure 12

ESTIMATED ANNUAL BIOMASS PRODUCTION FROM GRAINS AND GRASSES
FOR LAND RESOURCE AREAS (LRA), RANK ORDERED ON COLUMN 10 OF THIS REPORT

SCENARIO TITLE: RESIDUES, SPOILED FORAGES AND NEW CROPS

FOOD CROPS INCLUDED: TCOR CORN WHEA BARL RYE OATS SORG SOY RICS HOPS SUNF SAF PEAH
LAND TYPES: 0.80 TCOR 0.80 CORN 0.80 WHEA 0.80 BARL 0.80 RYE 0.80 OATS 0.80 SORG
0.80 SOY 0.80 RICS 0.80 HOPS 0.80 SUNF 0.80 SAF 0.80 PEAH
FORAGE CROPS INCLUDED: CORS CORG SORS SORH SORG ALFA CLOV SMAL OTHR GRSS GREN
LAND TYPES: 0.10 CORS 0.10 CORG 0.10 SORS 0.10 SORH 0.10 SORG 0.10 ALFA 0.10 CLOV
0.10 SMAL 0.10 OTHR 0.10 GRSS 0.10 GREN
GRASS CROPS INCLUDED:
LAND TYPES: LESS NEW CROPS ON LAND USES 3, 4, AND 8

NEW CROPS INCLUDED: KENF REED CATT GUAY GUYM
LAND TYPES:
KENF LCC: 1 2 3 5 6 7 9 10 11 13 LUC: 0.0 (2) 0.10(3) 0.10(4) 0.10(8) 0.0 (5) 0.10(6)

REED LCC: 18 19 21 22 23 25 LUC: 0.0 (2) 0.10(3) 0.10(4) 0.10(8) 0.0 (5) 0.10(6)

CATT LCC: 4 8 12 16 LUC: 0.0 (2) 0.10(3) 0.10(4) 0.10(8) 0.0 (5) 0.10(6)

GUAY LCC: 1 2 3 5 6 7 9 10 11 13 LUC: 0.0 (2) 0.10(3) 0.10(4) 0.10(8) 0.0 (5) 0.10(6)
18 19 21 22 23 25
GUYM LCC: 1 2 3 5 6 7 9 10 11 13 LUC: 0.0 (2) 0.10(3) 0.10(4) 0.10(8) 0.0 (5) 0.10(6)
18 19 21 22 23 25

(AREAS ARE IN THOUSANDS OF ACRES AND YIELDS ARE IN THOUSANDS OF AIR-DRIED TONS)

1 LRA NO.	2 TOTAL AREA	3 FOOD CROP TOTAL YIELD	4 FOOD CROP RESIDUE YIELD	5 FORAGE CROP YIELD	6 GRASS CROP YIELD	7 NEW CROP YIELD	8 TOTAL BIOMASS YIELD	9 BIOMASS PRODUCTION AREA	10 AVERAGE BIOMASS PRODUCTION TONS/ACRE
156	5809.	0.	0.	1.	0.	3367.	3367.	175.	19.2
155	9702.	0.	2.	8.	0.	4432.	4442.	239.	18.6
154	4523.	0.	1.	5.	0.	1846.	1851.	112.	16.5
81	19883.	0.	89.	12.	0.	12545.	12646.	1687.	7.5
82	1201.	0.	8.	0.	0.	459.	463.	64.	7.4
92	842.	0.	1.	1.	0.	17.	19.	3.	6.8
93	15495.	0.	121.	55.	0.	1062.	1233.	186.	6.7
83	21931.	0.	1144.	37.	0.	14595.	15777.	2412.	6.5
87	8915.	0.	346.	35.	0.	3803.	4183.	650.	6.4
94	11711.	0.	134.	50.	0.	923.	1107.	179.	6.2
19	3228.	0.	7.	3.	0.	649.	658.	107.	6.1
SUBTOTAL	103239.	0.	1854.	206.	0.	43697.	45757.	5814.	
TOTALS	1895418.	0.	239407.	12172.	0.	232464.	484046.	[illegible]	

Figure 13

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: RESIDUES, SPOILED FORAGES AND NEW CROPS ON ~ 10% GRASSLAND

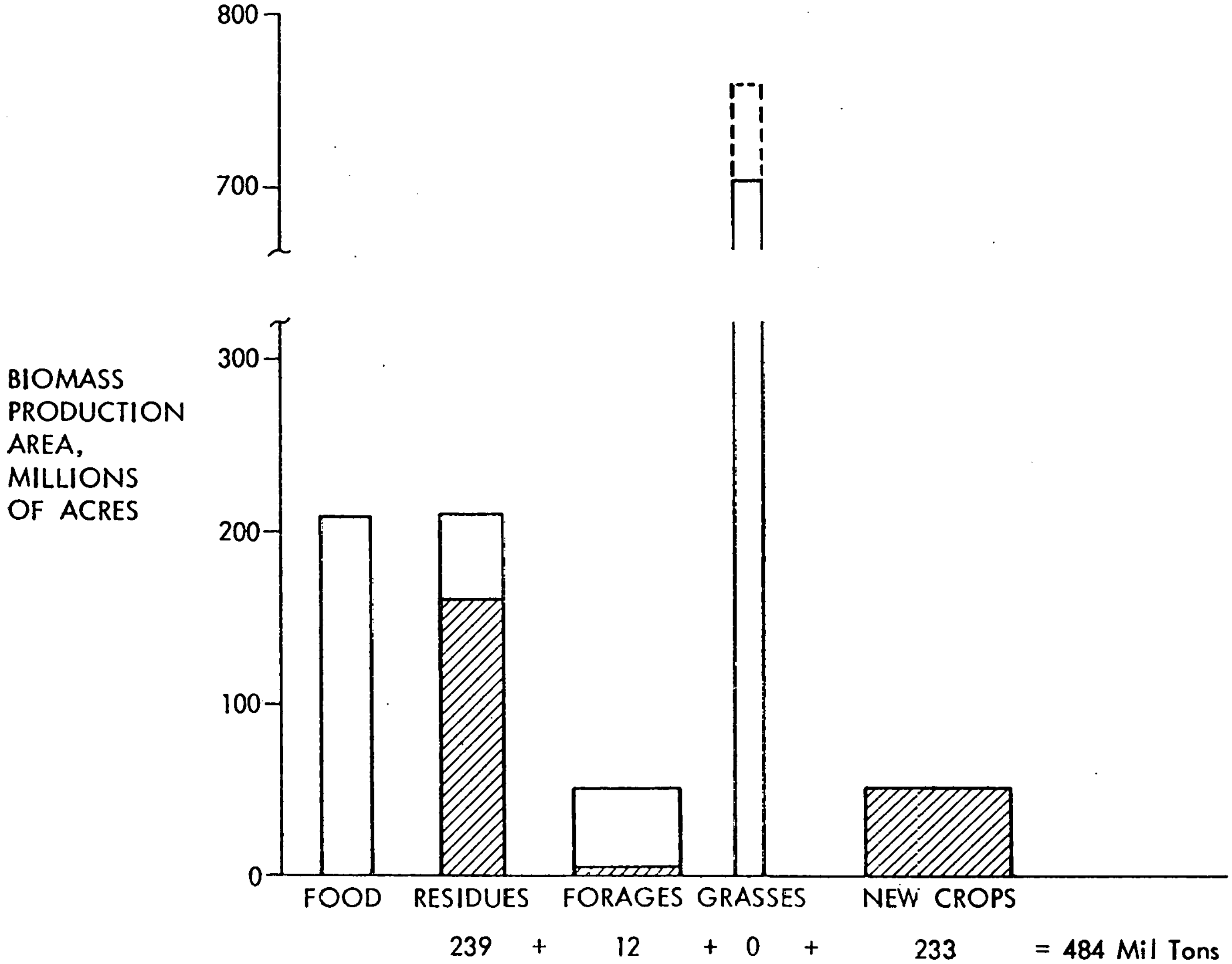


Figure 14

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: LIMIT GRA N FED TO CATTLE TO THOSE OVER 700 LBS

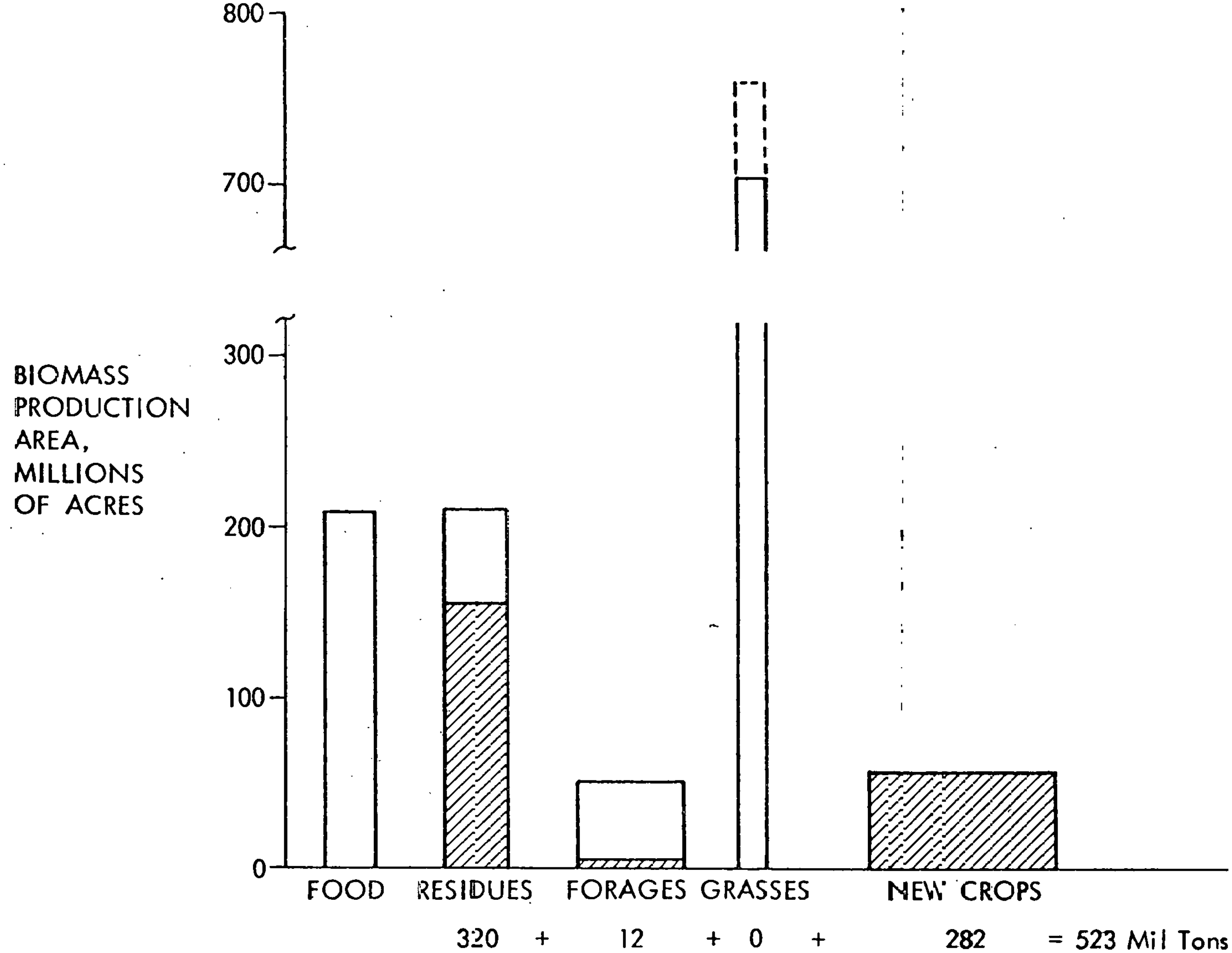


Figure 15

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: LIMIT GRAIN FED TO CATTLE TO THOSE OVER 900 LBS

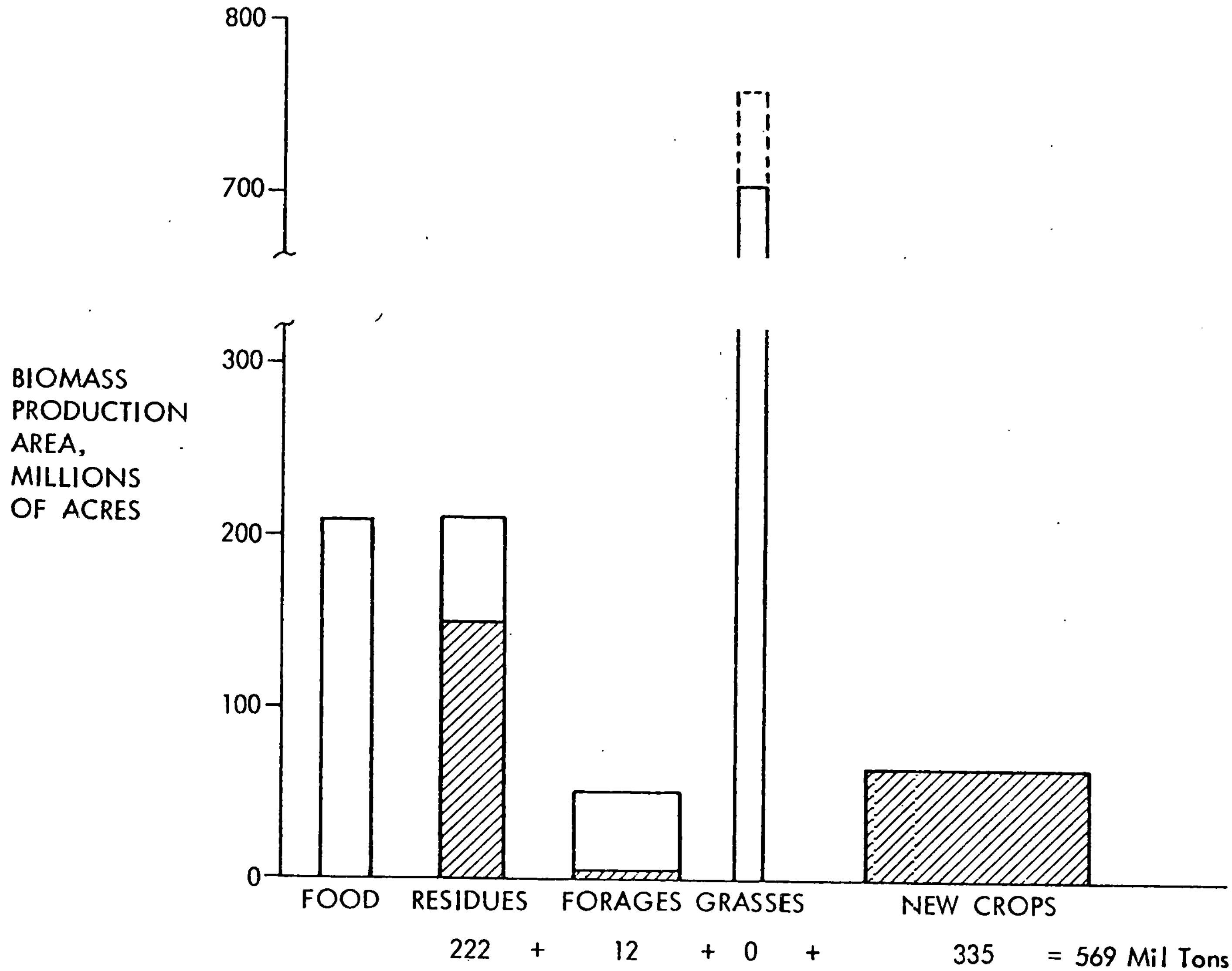


Figure 16

A third scenario relates to the feeding of grain to no cattle under 900 lb or over 1,100 lb. The yield potential is further increased to 579 million tons, see Figure 17.

Another approach to providing additional lands for biomass production is to consider alternatives to the exporting of grain. For example, since the U.S. exports 60% of its wheat, range numbers of acres are devoted to wheat for export. If a national policy decision were made to reduce those exports, additional lands would be available for the production of biomass. One such scenario is to reduce current exports by 25%. The biomass yield potential is increased to over 600 million tons per year, as shown in Figure 18.

If exports were reduced by 50% the potential yield increases to 724 million tons, see Figure 19. If it were possible to eliminate all exports of grain the potential biomass yield would be 778 million tons annually, see Figure 20.

We are not suggesting that any one of these scenarios is necessarily feasible. They are intended to illustrate possibilities for other land use scenarios favoring biomass production.

The biomass potential from grains and grass sources under selected land use scenarios is summarized in Figure 21. These estimates can be expressed in millions of air dry tons per year, and also as potential energy, in quadrillion Btu's per year. Considering only 80% of the residues and the spoiled forages, there is a biomass availability of 252 million air dried tons with an energy potential of 4 quadrillion Btu's. To put that in perspective, the total nuclear power industry with 45 plants on stream, more or less, is currently producing somewhat less than 2 quadrillion Btu's of energy.

If new crops on 10% of the marginal lands are added to residues and spoiled forages, the biomass potential is increased to 484 million tons or 7.7 quad. Limiting the amount of grain fed to animals, has the potential for increasing that potential biomass energy availability to 8.4 quad, 9.1 and 9.3 quad, respectively for those scenarios.

Reducing grain exports, has an even greater potential to increase the availability of biomass. If grain exports are reduced 25% as air independent scenario, the energy available from biomass would be 9.6 quadrillion Btu's. Elimination of all grain exports could provide 15 quadrillion Btu's. The entire United States utilizes approximately 78 to 80 quadrillion Btu's annually for all energy requirements.

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: LIMIT GRAIN FED TO CATTLE TO THOSE GREATER THAN 900 LBS BUT LESS THAN 1100 LBS

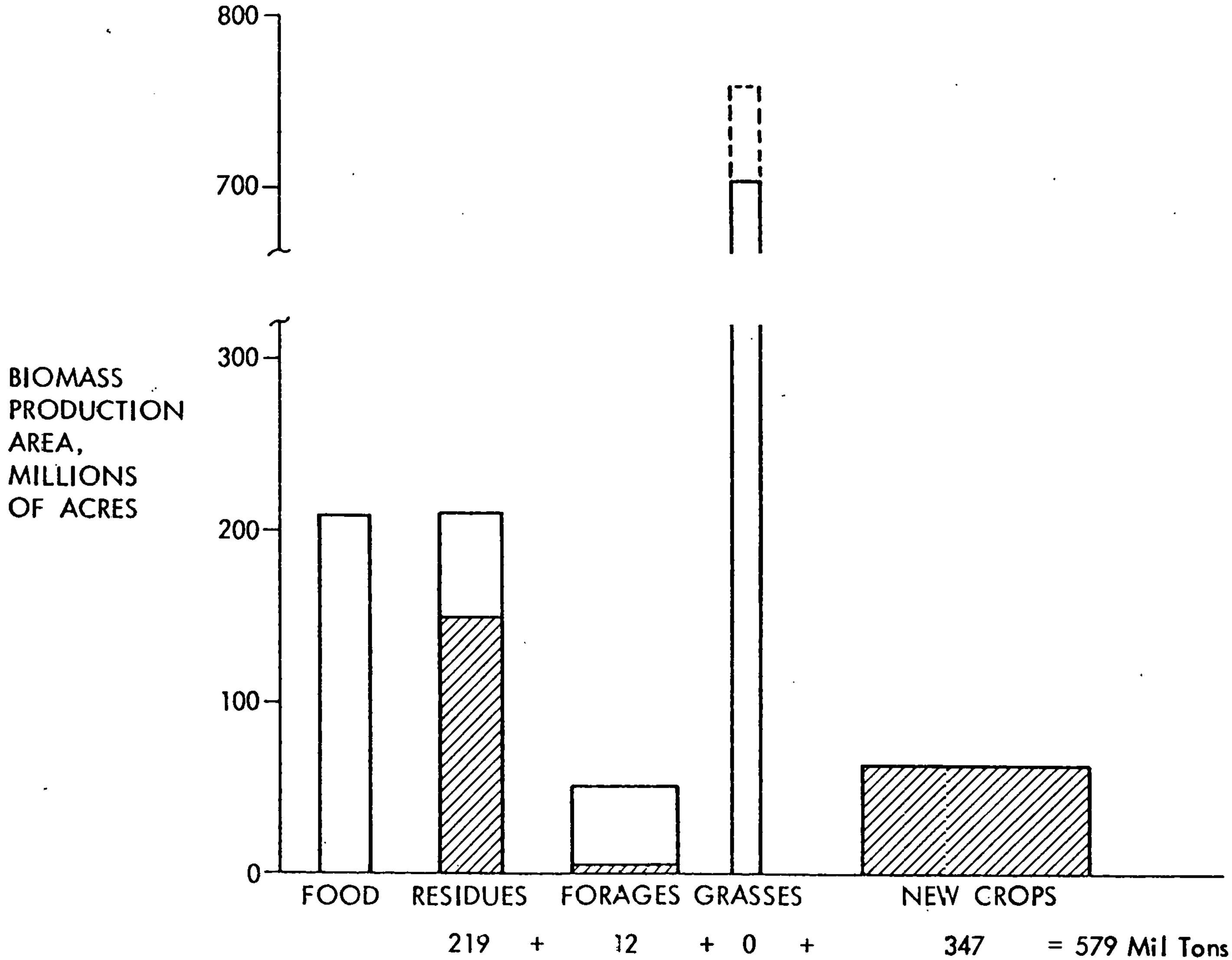


Figure 17

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: REDUCE GRAIN EXPORTS 25%

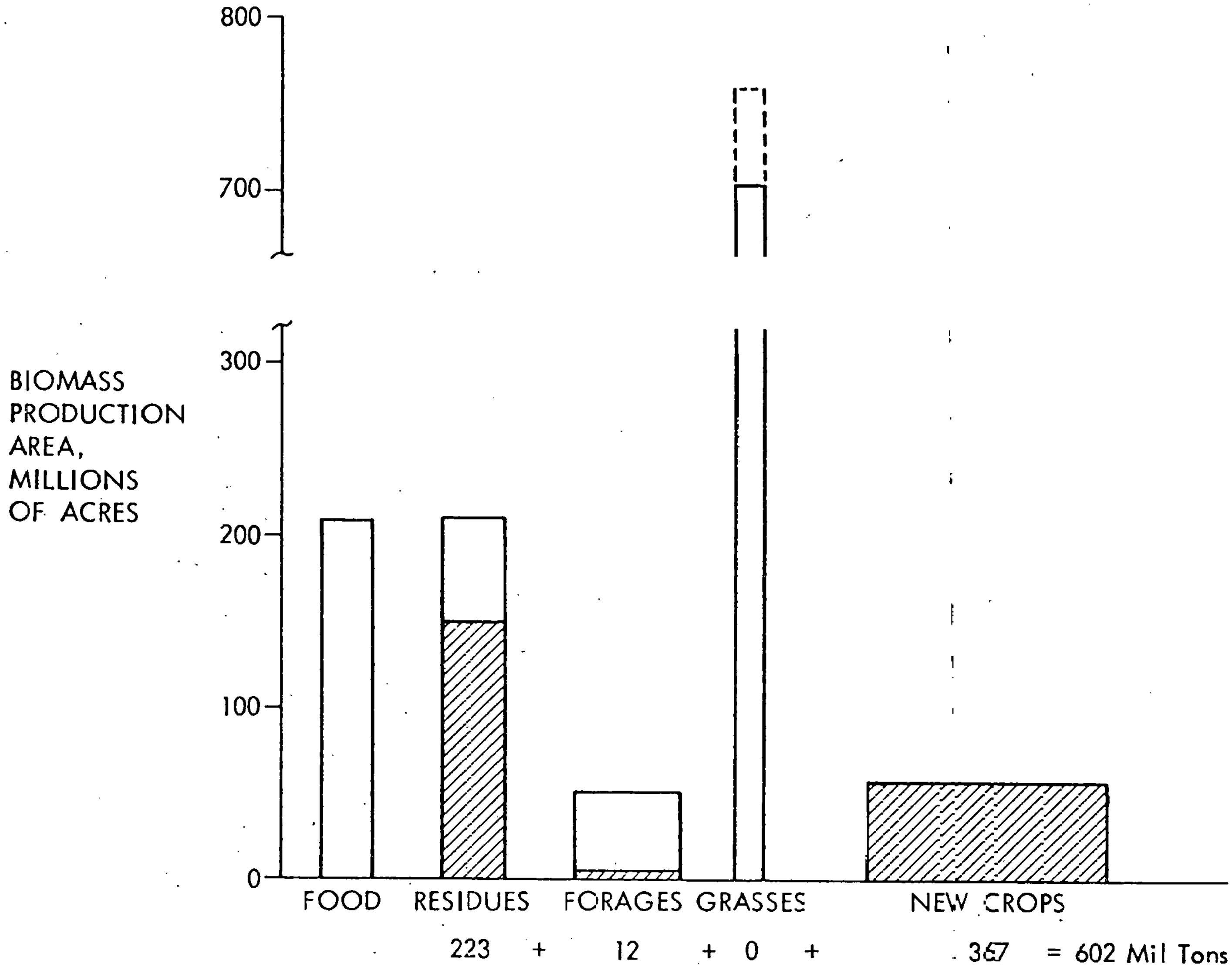


Figure 18

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: REDUCE GRAIN EXPORT 50%

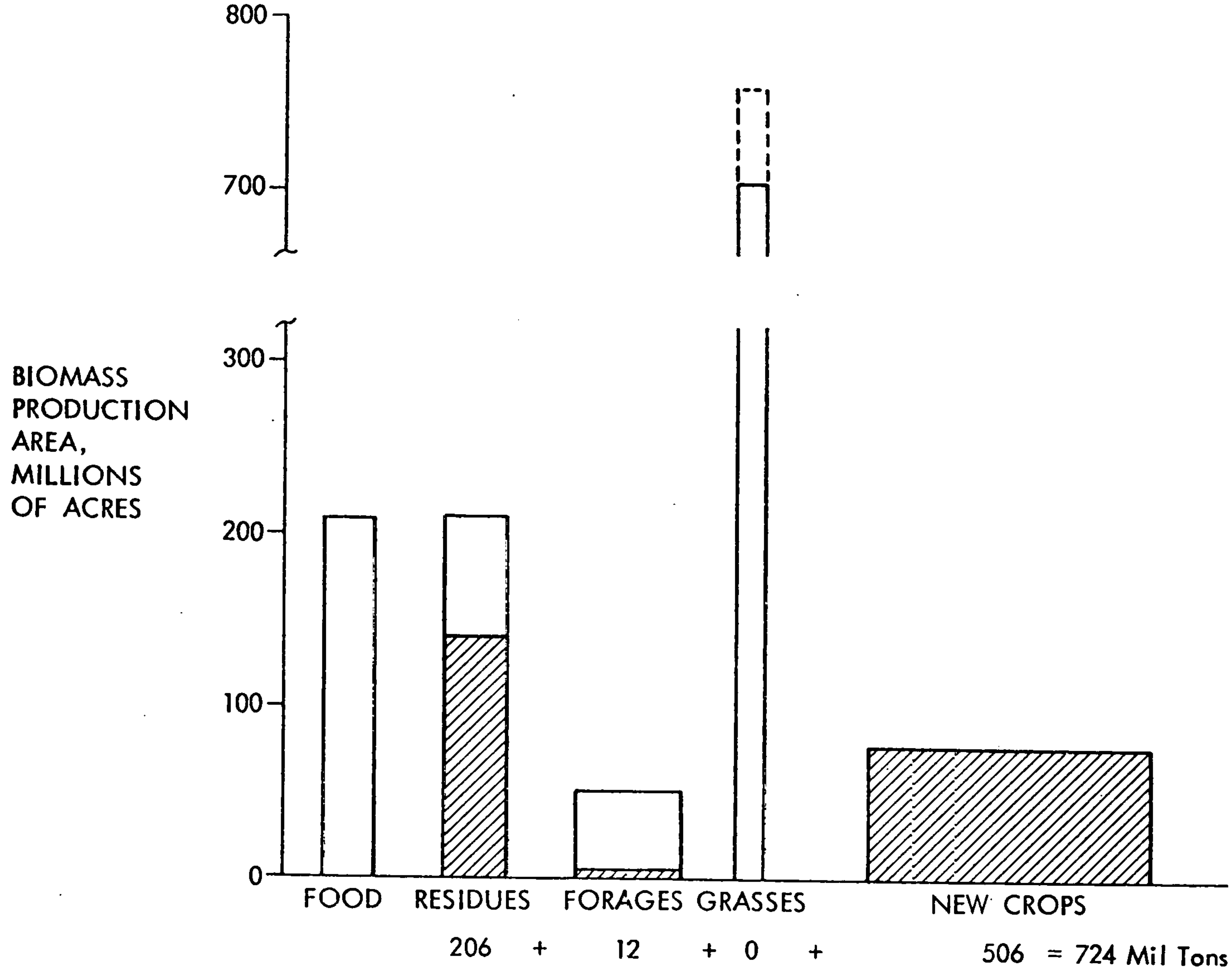


Figure 19

BIOMASS AVAILABILITY DISTRIBUTION

SCENARIO: REDUCE GRAIN EXPORTS 100%

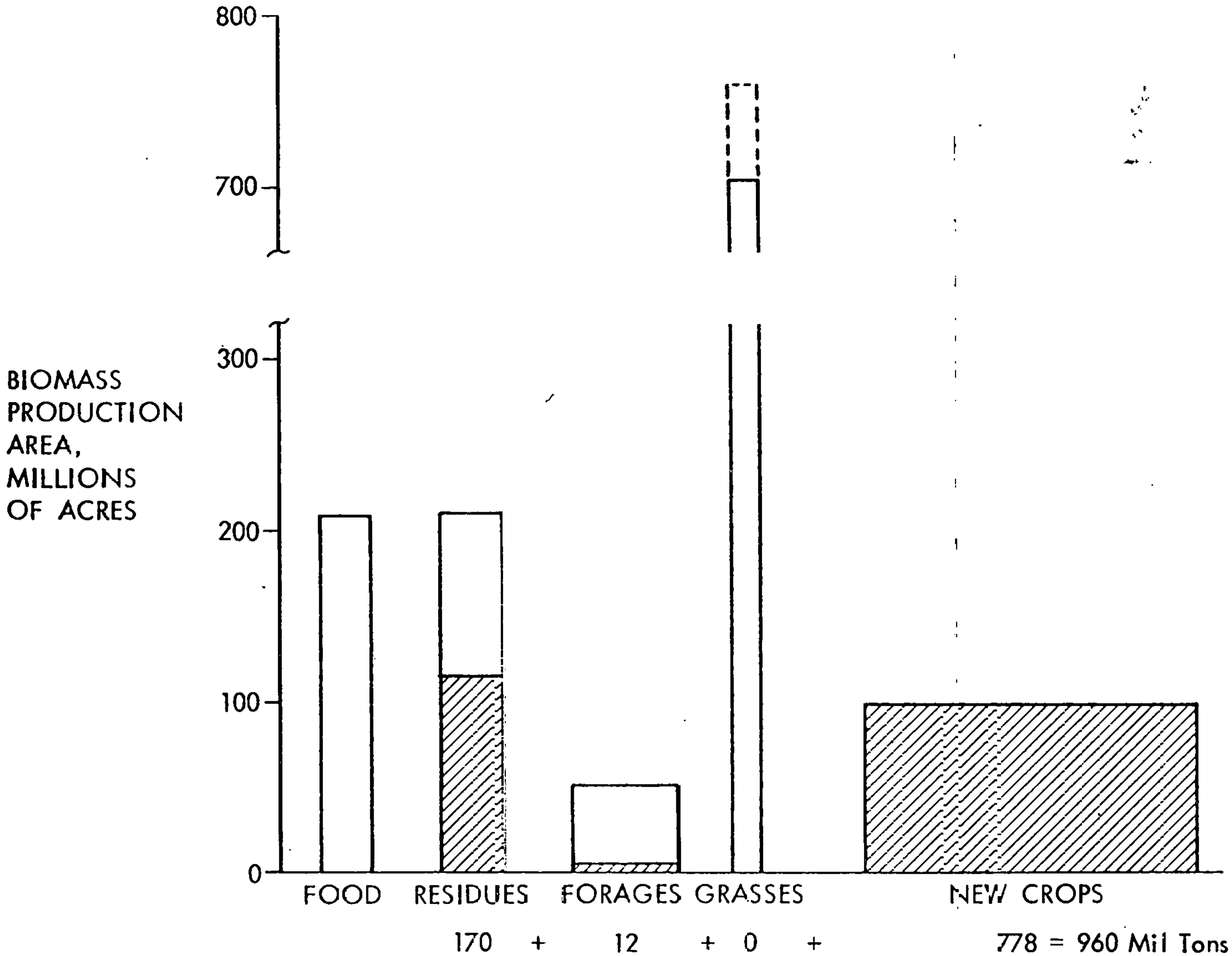


Figure 20

Potential Biomass Availability For Selected Land Use Scenarios

Scenario	Total Biomass, Millions of Air Dry Tons	Potential Energy 10^{15} Btu*
1. Residues, Including Spoiled Forages	252	4.0
2. Residues, New Crops on 10% Marginal Land	484	7.7
3. Only Feed Grain to Cattle >700 lbs	523	8.4
4. Only Feed Grain to Cattle >900 lbs	569	9.1
5. Only Feed Grain to Cattle >900 <1100 lbs	579	9.3
6. Reduce Grain Exports 25%	602	9.6
7. Reduce Grain Exports 50%	724	11.6
8. Reduce Grain Exports 100%	960	15.4
A. Add Reduce Grain Exports 25% Scenario to Only Feed Grain to Cattle >900 lbs Scenario.	+135	+2.1
B. Increase New Crops on Marginal Land to 25%	+349 +	+5.6
C. Increase New Crops on Marginal Land to 50%.	+930	+14.8

*Assuming Average Heat Value of 16 x 10^6 Btu per Air Dry Ton

Figure 21

If the reduced grain exports by 25% scenario were added to the only feed grain to cattle over 900 lb scenario, another 135 million tons of biomass is added with the potential of an additional 2.1 quadrillion Btu of energy.

If it could be technically, and economically feasible to increase the utilization of marginal lands to bring 25% or our current rangeland into new crop production, an additional 5.6 quadrillion Btu's could be added to the energy potential from biomass. While probably not feasible, if 50% of the rangeland in the United States could be brought into new crop production, almost 15 quad of energy could be produced.

The potential availability of biomass from grain and grass sources has been clearly demonstrated. What remains to be done, is to investigate thoroughtly the economic and technical feasibility of making large quantities of biomass available to a conversion plant site. The feasibility of alternative conversion processes also has yet to be demonstrated.

A CASE STUDY OF BIOMASS FARM MANAGEMENT

R. C. Mathews, Director Production,
Farm and Ranch Management Division

Doane Agricultural Service, Inc.

At Doane Agricultural Service, we have been working on the Biomass Farm Management project several weeks and we haven't got all the answers by any means. This discussion is more in the line of a progress report rather than a final, conclusive report.

Currently, we are looking at the use or production of biomass from the standpoint of a practical farm operation in order to determine the financial returns and possibility of producing biomass in competition with other crops. In doing this, we first selected, with the help of MRI, three farms. We had one farm in Kansas, one in Iowa and one in Mississippi. These three farms were to be used for our analysis.

The Kansas farm is about a 3,000-acre wheat farm. Some sorghum is also grown there. There is no irrigation of any significance there.

The Mississippi farm is approximately 1,500 acres. It's land is devoted to cotton, soybeans and pasture.

The third farm, and the one that we are primarily concerned with in this report, is in Iowa. Actually, there are three parcels to the farm. The total acreage is 1,039 acres and the units are not contiguous. They are spread about 10 miles apart. One of the parcels of the Iowa farm is about 10 miles from Ottumwa and the other two parcels are about 11 miles from Fairfield. All three are in southeast Iowa.

These three parcels of land are currently being operated on a grain share operation. The operator is actually renting the farms. However, we are approaching the analysis from the total farm standpoint. The operator has normally been devoting 50% of his land to corn and 50% of his land to soybeans. He has also raised a small amount of oats and a little hay.

The Iowa farmer has four tractors. One of them is a 275 horsepower 4-wheel drive John Deere. He has 125 horsepower and 295 horsepower tractors, 30 foot offset disc, one 7700 John Deere combine. He's a good John Deere man and he is stuck with the John Deere equipment. Normally, one would think with this horsepower lineup that he's a little overpowered, but this is the usual rather than the unusual nowadays.

Now, from the labor standpoint, he has his wife, two daughters, son-in-law and part-time hired man, so he has a lot of help there. The wife and daughters will work when it's necessary. The son-in-law, the part-time hired man and the operator do the bulk of the work.

The soils on this farm are basically Grundy Haig as well as a few other soil types. It has Kola, Arispe, Rinda Pershing and Armstrong soils. Actually as it's classed by the Federal Government, there are no Class I soils on this farm. There are Class II soils on the level upland, which would be Grundy and Haig soils. Haig soils are the more level. The Haig soils tend to be a little on the wet side, which occasionally causes problems.

The Grundy soil is on the slope. Some of the other soils are Class III and IV soils. The slopes are fairly sharp here and the farmer is farming some on the contour, so he is using some soil conservation measures. He has even done some terracing on these slopes.

The farmer in this case does not differentiate between soil types. He farms it all. Keeping soil losses down to 5 tons or less per acre per year is an impossibility on this farm the way the operator is farming it. We ran some analyses and we determined he might be able to keep soil losses down to 20 or 25 tons per acre if he were careful, but realistically, the losses are probably in the range of 30 or 40 tons per acre per year. We have to look at the farm operation from the standpoint of what the farmer will do today. We can talk about trying to keep soil losses down to 5 tons per acre, but that's not realistic as most farmers aren't controlling their losses unless they are on a strictly grass operation.

Now, let's examine the climatic data. Average rainfall in southeast Iowa is a little higher than 34-1/2 inches per year compared to about 32 inches per year for the state. Average monthly temperatures for southeast Iowa are 48 to 51 degrees.

It's interesting to note that the state as a whole has less rainfall than southeast Iowa, but in several months, May and June and August, the state has more rain than southeast Iowa. These statistics are based on 30-year records.

Our first analysis on this Iowa farm is a benchmark analysis using current crop production and how it might relate to biomass. In other words, this analysis will determine the possibility of producing biomass from current crops. This first step gives us a baseline to work from. In this analysis we are preparing unit budgets on each crop that's suitable for biomass production, as well as on the other crops grown. These unit budgets are then run through a linear programming analysis to get the mixture of crops that will optimize both income and biomass yield.

So far we have analyzed the current crops (corn, soybeans, and oats), on the Iowa farm. We have not gotten into analyzing specialized biomass crops.

So, using a budget generator, we input all the items as they existed on the farm. (Our price levels are basically last quarter or current price levels.) We made about 17 different budgets all together. One group of budgets was made for conventional farming and one group was made for basically conventional farming utilizing the residue for biomass. The third was using crops entirely for biomass. And the basic results were as follows:

On the normal cropping program the soybeans came in as the most profitable crop under this particular set of conditions. The net return of land, labor and management on the 783 acres of tillable land was $124,000.

On the normal cropping system plus using the crop residues, we approached it from the standpoint that we could use 33%, 67% or 100% of the biomass recovery and we changed the amount of fertilizer required to what we hoped would offset the loss of the residue. But on the normal plus biomass, the corn, using a processed yield of 100%, returned the greatest amount. Net return to land, labor and management there was $156,000, which is larger by about $30,000 than the normal cropping program. So if our assumptions on productivity are correct, which they probably aren't, we could say the farmer would make $30,000 more a year, roughly, by selling all his residue as biomass.

Next we considered biomass production alone. Soybeans when analyzed for biomass production alone resulted in a net loss of income. Because of the low volume of biomass production, sale of soybeans for biomass don't meet the cost of production even when soybean grain was figured in the total production. So soybeans have no place in biomass production.

Since soybeans weren't profitable for biomass production alone, we next looked at corn. Corn was assumed to be mature corn, the growth was complete. Operating under these assumption, the corn's net returns came out a hundred eleven or a hundred twelve thousand dollars. Thus, corn for biomass production alone wouldn't compete with the current sale of corn or soybeans under the price situation that we employed there.

It might be interesting to note that on corn for biomass only, the unit budget showed a return of $143 an acre and soybeans for biomass only was negative $27.75 an acre. Oats for biomass had a positive $30 return per acre.

We have several more analyses to make to arrive at better answers. One of the things we are going to have to do is to break down the land class into more groups. The farmer actually farmed it as one unit and he didn't vary the fertilizer or anything from one area to another. And while this practice is common to most farmers, from an analysis standpoint we need to differentiate between the soil types. This will be one of the things which we will do in subsequent analyses.

Another analysis we need to make is to refine the effect on soil productivity from the removal of biomass. This is one of the things that is critical to a good analysis of biomass potential and yet is very difficult to arrive at.

Another item demanding further attention is the transportation of biomass. Thus far we charged transportation in at two dollars and a half a ton, which is equivalent to hay hauling charges in that area. We felt this was fair at that point in time. However, we are going to have to look at that again to refine these cost figures.

Harvesting biomass was considered from the standpoint of four different systems. These four systems were the small baler, the large round baler, the 3 ton stacker and a chopper for straight biomass. The cost between the stacker and the large baler was insignificant, it was 2 cents difference in the budget. So it looked to us like it's a toss-up between which of the two systems to use. There is some difference in cost between the small baler and the chopper. However, there are some new developments in machinery which could change these cost estimates, so we will have to look further into the cost of harvesting biomass.

Then, of course, we will have to look into some of these exotic crops, like kenaf, that may be suitable for biomass production. Not too many of these exotic crops are suitable for Iowa, but in some of the other areas they may be more suitable.

Now, let's make some tentative conclusions.

The utilization of refuse seems feasible. Until the value of biomass exceeds the value of grain, biomass production is not feasible. So when we have corn at two dollars and a quarter a bushel. it takes precedence over $40 a ton biomass, which is the value of biomass that we used in these calculations. In addition, the removal of biomass is not feasible unless the value of the crop removed exceeds the cost of additional fertilizer, collection and transportation, which it didn't in the case of soybeans. As a matter of fact, in the case of soybeans, the more biomass you took off the less money you made, so it was a self-defeating process.

Another factor that's extremely important is that rather small changes in prices will significantly alter our conclusions of biomass potential. For example, if corn was $2.50 a bushel instead of the $2.25 a bushel used in these analyses, biomass production would not be very profitable.

QUESTION: You said biomass was worth $40 a ton. I believe that's way out of line. That makes us over $2 per million Btu's, which is way out of line in respect to coal or anything else, especially when you add the conversion cost.

ANSWER: The figure used was an average value of fuel furnished to electric utilities for 1975, $2 per million Btu.

QUESTION: You must be using the wrong figure for the efficiency of the boiler, because that's way out of line for the replacement fuel value. For bagasse, for example, you figure two barrels of fuel oil per ton of bagasse, and it can't be that much more. At $13 a barrel, that $26.

ANSWER: Coal was being provided last year at 95 cents a million Btu, gas, the figure was slightly less than a dollar, and oil was at $3 a million Btu's.

QUESTION: What you have got to compare with is coal. You are talking about double that price. You are talking about $2 a million Btu.

ANSWER: That's correct.

QUESTION: The other question I had is what's your hauling distance?

ANSWER: Approximately 10 or 12 miles.

COMMERCIAL USE OF CORN COB RESIDUE

Mr. William Hudson, Manager
Market Development

The Andersons

The Andersons is a grain exporting company. We export 2.5 million tons of grain, principally, corn. That would be, say, 20 percent of what Great Britain uses in a year. That's about 4 percent of the nation's total exports of all grains.

In tho aot of doing that we handle about 100,000 tons of corn cobs. These corn cobs are one of the diversifications of our company and what I principally want to discuss.

Back when this corn cob business started, we called it turning a minus into a plus. The corn cobs were a minus. They came with the corn, but there wasn't anything that could be done with them 25 years ago. That was before the combine came along. Back then the corn cobs were piled into block long piles containing maybe four or five thousand tons of cobs. These piles were then set on fire. And, just in case anyone wonders if there really is energy in that biomass, there is. Those piles of cobs would burn for months at a time and the more water you poured on them, the harder the fire would burn. It's called fermentation.

At the Andersons, we managed to turn this minus into a plus in a traditional case of American industry at work. This minus-to-a-plus is by means of technology and marketing.

The Andersons cob division today manufactures a wide range of corn cob products. The uses of these products will be discussed later in the report. Now, let's review where the program starts; it starts with the farmers. We at the Andersons are not as much of a research company as we are actual marketers, but we feel that the farmer who wants to get in the corn cob program today has to make a dedication to ear corn harvesting early in the game. He has to plant the corn so that it can be harvested on the ear. In other words, if he goes out in the fall and wants to harvest his corn on the cob, but he has planted and done his row spacing for shelling in the field, then he is not going to get much of an ear corn harvest.

The cobs used to be around in great quantity, but as the field-picker-sheller machine came into vogue, the availability of cobs went down. So at some point in time, maybe 10, maybe 15 years ago, somebody made a decision that we would start paying for the cobs. We now pay a premium of around 10 cents a bushel to get corn to us in the form of ear corn.

At harvest time, those farmers interested in selling both the corn and the cob, pick the entire ear of corn. There are still a couple of companies that make ear corn pickers, notably New Idea Farm Equipment Company of Ohio.

The ear corn then has the husks removed. A type of solar drying is one way of obtaining clean, husk-free ear corn. Now the corn is ready for cribbing, or field storage.

There are just about as many different kinds of field storage for ear corns as there are farmers. There are dozens and dozens of different ways to build a crib. There are some people from Purdue who have catalogged at least 2 dozen different ways to build a crib so that it maximizes the wind and sun energy that's available for any particular farm and so that is simplifies the loading and unloading procedures.

When corn is dried on the ear and the ears brought to us, the corn quality is absolutely superior. In other words, the amount of foreign material is negligible. The corn that is dried naturally and patiently on the ear doesn't break as much. We can document maybe a 7 or 8 percent savings in quality to the nation's corn crop. This savings in quality and energy obviously was not a factor when the John Deeres and International Harvesters started selling the field-picker-sheller. Then, energy was no cause. Of course, most companies were shortsighted in the fifties and sixties as far as energy was concerned.

Here is how the corn cob process starts from our standpoint. The trucks come in all year round loaded with ear corn. The trucks are then weighed and the quality of their load of corn is checked. Then the trucks are unloaded.

The unloading process is automated. The corn is dumped out the back of the truck onto conveyor systems which transfer the corn into a series of six parallel shellers. So the corn kernels are separated at this point and started on their way in the export stream.

The next step is to reduce the size of the corn cobs. A set of revolving hammer mills is used for this step. Cobs come out of there about 1 inch long. Then they go into a tumbler type of dryer. The cobs are dried to a 6 to 8 percent moisture content in order to get them to grind right.

In 1958, our contribution to the technology of corn cob processing was to perfect certain existing roller mills. A cob is a pesky creature. They are hard to grind, very hard to grind. Before beginning the grinding process, the cob, particularly the woody-ring portion, has to be sheared apart. You can't hammer the cob because it simply compacts. The cellulose is in a fibrous bundle and it sticks together and just gets harder and harder as it is hammered. It doesn't break. So our contribution to the technology has to do with the way we split the cob.

We also made a contribution in separating the three portions of the cob. The three portions of the cob are the part that holds the corn on the cob (called bees wing thread), the woody-ring portion, and the center or the pith. The woody ring makes up 60% of the cob by weight, the bees wing and pith make up 40%.

Now, we make a separation of the pith and bees wing one way and the woody-ring another. The woody-ring is four times as hard as maple and, therefore, it commands a high price as an industrial abrasive. The pith and bees wings are soft, dusty, icky, hard to handle, so we pelletize that material and sell it as animal feed.

One of the things we do well and are proud of is removing the dust from the pith and bees wing. This helps us to sell against other corn cob makers..

We also made some patented advances in the grading of products, sizing, and classifying the different sizes. Corn cobs are brought to us in all different sizes and grades and we have found markets for the different size ranges.

The final tool that we use in the grinding process is an attrition mill, which involves two large spinning plates, and this takes the cob on down to the finest size to which we can get it.

In addition, we have a lot of quality control going on. If we don't hold our quality standards, it's like any other product. The customer won't buy it. There are a lot of automated and computer type controls in one of these factories, as there are in any other modern day factory. Included in these controls are safety and OSHA concerns.

The end products of the corn cobs are separated into four different grades which we call Grit-O' cobs, Lite-R cobs, Bed-O' cobs, and Slikwik. The Grit-O' cobs comes from the grit, the woody portion and they are used in tumbling and soft-grit blasting, finishing of plated metal parts and dry cleaning. However, their most important single use is as an absorbent carrier for agri-chemicals. One agri-chemical they are used in is insecticide. Corn cob is very absorbent and provides a time release for the pesticides that are of a systemic nature. Another agri-chemical use for Grit-O' cobs is an extender of lawn products. Here again their role is to absorb the pesticide. The American householder is not very adept at using liquid products, so the product must be extended for him.

The important use for the Lite-R cobs, which is made from the pith and bees wings, is as roughage in cattle feed. There is no protein in the cob to speak of, but the cow's rumen can break the cellulose bonds in the roughage down into glucose.

The Lite-R cobs are also used as an oil slick absorbent that we call Slikwik. This Slikwik can be loaded on oil tankers and dumped on an oil spill, when necessary. This process works quite well; the cell is absorbed rapidly. The speed of absorption is quite fine for corn cobs that have been dried down to the 10 percent range. So we have sales of these products in all of the major countries.

We are into the research and development of new uses. A good deal of time and money was spent trying to understand a new use in the chemical area called xylatol, which is a new sweetener. It's made out of the five carbon parts of the cob.

Cob is an interesting creature from the chemical standpoint because it contains around 5 to 6% lignin, which is less than the amount contained in wood. Also, there's around 28 to 30% cellulose in corn cobs, and by cellulose I mean the 6 carbon family that are linked together. And, there is around 35% of the 5 carbon family in cobs. What this all means is that the cobs turn out to be possibly the richest source of xylose under the sun on a pound-per-pound basis.

One of the obvious uses of corn cobs is to burn them. Fifteen or twenty years ago, The Andersons did burn them for fuel. When the cobs are burned, they release potassium oxide as they contain a substantial amount of potassium. This potassium oxide eats up the grate of the typical furnace. That's not a big technical problem for a company like Hughes Aircraft or General Electric, but for a company in the American grain industry with two engineers to work in the problem, it can be a tough one to solve. So we used what we call a moving grate burner 15 years ago. The product of the direct combustion was hot air and this hot air went into our grain dryer.

Now, as these other industrial uses developed and the cobs got more expensive, they got to be worth too much to burn. Therefore, up until last year, they were worth too much to burn. But now the energy picture has changed all that.

During the past year, we have built a fluidized bed burner to overcome this potassium oxide problem. Our engineer, Bob Anderson, has been trying to get the burner to work as our intention is to convert over to corn cob power next year. We will unearth our old moving grate furnace and do our grain drying with cobs.

The economics of the corn cob business is an important consideration. The ear corn premium that we pay is around 10 cents a bushel. Now, a bushel of ear corn weighs 70 pounds, and about 10 pounds of that is cobs. That's the figure we have found to be correct in our experience. So at 10 cents a bushel and 10 pounds to the bushel, cobs cost around $20 a ton. This $20 a ton figure will vary throughout the year as we vary that premium in order to even out the inflow of cobs all year long. That way we get cobs 365 days a year. So the price of cobs comes out to be approximately a penny per pound and we've found that most farmers will haul most things for around a penny a pound. Our average hauling distance is probably 70 miles. We draw from the tip of Michigan down to Toledo, and we draw from Pennsylvania and southern Ohio. So a lot of people come from 150 to 200 miles with ear corn. It would be possible to get all the cobs wanted from a 25-mile radius, but, farmers are just as diverse as other groups, and they won't all haul their cobs to be sold.

Now, the cobs, the soft part sold as feed currently brings around $40 a ton in the United States. Then the cobs as grit sell for $110 a ton, which is worth more than the corn itself. And the cobs used for fuel are worth $46 a ton as compared on a Btu basis to current propane prices.

So that's the story of turning a minus into a plus as well as the story of one of the two or three companies currently operating in the biomass area. Quaker Oats is the furfural maker and I think they handle over twice as many cobs as we do. We handle a total of 100,000 tons, so between Quaker Oats, us, and the other corn cob grit producers, there is maybe half a million tons of cobs in use.

ALTERNATIVE ORGANIZATIONAL AND MARKETING ARRANGEMENTS FOR MARKETING BIOMASS

By

Dr. William E. Black*

This paper will identify the alternatives of business organizations and marketing arrangements that might be developed to transfer biomass from production to conversion plants.

Requirements for Feasible Marketing Systems

What are some requirements for an economically feasible biomass marketing system? (Not listed in order of importance.)

1) Willingness: -- Willingness must exist on the part of farmers and ranchers to produce and sell biomass to converters and for converters to establish and operate biomass conversion plants. The need for generating fuel and chemicals from biomass is not yet urgently felt by farmers and ranchers. A substantial Educational program is needed to develop this awareness.

2) Adequate Income: -- Net economic benefits to producers must be sufficient to prompt his participation in the system. The basic question is -- how much of the crop residues will farmers plow under and how much of it are they willing to market as biomass? The critical issue is the impact of biomass removal from the farm upon future land productivity. Biomass is not a free good when measured in terms of future production potential of the farm.

---

*Economist-Marketing and Policy, Texas Agricultural Extension Service, Texas A & M University, College Station, Texas. This paper was presented March 2, 1977, in Kansas City, Missouri, at the Conference on the Production of Biomass from Grains, Crop Residues, Forages and Grasses for Conversion to Fuels and Chemicals.

3) Adequate Volume: -- Volume sufficient must exist to operate at an acceptable point on the average cost curve for production, assembling, conversion, and marketing. Once the projected and break-even costs are known, then the alternative is to. . .

(a) Fix the plant size and vary the geographic area for biomass production or,

(b) Fix the geographic area and vary the plant size.

The relative importance of economies of scale -vs- hauling costs will determine the limits of geographic area.

4) Accurate Commodity Description: -- If we assume that conversion plants will obtain biomass via contracts, then an accurate basis for describing what is to be delivered by the producer and received by the plant must be developed. This description should also relate to the value of the biomass. Thus, a grading system reflecting use value or BTU potential of various types of biomass must also be established.

5) Contract Performance Guarantees: -- A contractual arrangement must be developed that accommodates the production cycle on farms. This means that a pricing and marketing system be developed that permits producers and converters to live up to the terms of the contract. For example, if farmers insist upon removal of biomass before a deadline date this means that the system must be developed that allows the accumulation of a year's volume in a few weeks. The contract must include penalty clauses to assure compliance.

6) Mutuality or Equity of Treatment of Various Parties to the Contract: -- A system must be devised that allows the producer to participate in the ultimate market pricing of the products generated. Will the contracts be written by producers and converters and will they reflect mutuality in contract terms? A contract developed by the converter and offered to the producer on a take-it-or-leave-it basis may prove unworkable. Contract terms must relate benefits and costs to each party.

7) Commitment: -- Pre-season commitment of biomass by the producer to the converter is necessary for a substantial portion of the biomass volume. Any system of converting biomass to fuels and chemicals which depends exclusively upon the spot or open market for biomass will probably prove unworkable. This means that producers will enter into contractual arrangements with converters prior to the time the biomass becomes available. Commitment, therefore, provides predictable supplies and reduces the investment risk in the converting plant.

8) Workable Contract Base: -- Acreage rather than tonnage will probably be the basis for contracting biomass. Acreage contracts mean that the producer will transfer to the converter all the biomass produced on a defined acreage. Tonnage contracts would lead toward limited commitment of production to the converter because of the bulk, limited market for biomass between producers, and the risk the producer takes in being able to perform on the contract.

9) <u>Integration</u>: -- Integration of two or more stages in the production-processing-marketing complex would be encouraged if biomass can be economically converted into fuel and chemicals. The most economic potential conversion for biomass probably exists at cotton gins and rice mills. Saw mills and sugar cane mills are currently directly converting their by-products into energy. Roasting of peanuts may be feasibly done at the shelling plant to economically utilize peanut hulls. By the way, peanut and rice hulls are currently being shipped from Texas processing plants to West Texas feedlots as cattle feed. This is one form of energy conversion somewhat different than used for roasting.

If the emphasis in the industry is on integration then the emphasis in technology will probably be to develop individual farm fuel converters. Dr. Richard Wainerdi, Associate Vice President for Academic Affairs - Texas A & M University, thinks that farmers will be able to buy a farm fuel converter within the next ten to twelve years. There are three advantages of a farm converter over a community plant system.

(a) No tax on the fuel generated by the farmer and used in his own tractors and farm equipment.

(b) Avoid the biomass transportation and storage costs.

(c) The resulting fuel is less apt to be allocated away from the producer.

Whether it will be farm units or commodity units depends on relative economies of scale.

10) Diversification: -- Cluster various types of industries or multi-product businesses around available biomass. For example, there are seven times more BTU's in cotton gin trash than energy used by the gin. This suggests an opportunity for another industry to locate near the cotton gin to utilize energy from available gin trash.

Organizational Alternatives

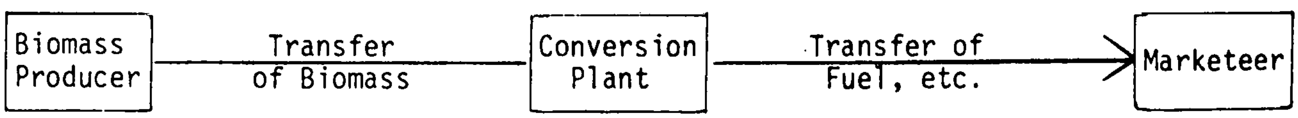
While we have three types of businesses, I anticipate that few large scale community-based biomass conversion plants will be owned by individuals or partnerships. Thus, corporations are most apt to own large scale community based plants, and they can be one of two kinds -- ordinary or cooperative.

In an ordinary corporation those who invest hope for a profit but most likely will not be the providers of biomass nor the users of the end products. A cooperative is owned by the people who do business there. A cooperative conversion plant would be owned by farmers and ranchers who provide the biomass and utilize part or all of the resulting fuel or chemicals.

Regardless of corporate type, joint venture arrangements are also feasible. For example, a group of producers producing biomass may belong to a cooperative which enters into a joint venture arrangement with a marketing cooperative or regular corporate marketing firm to market the generated products. In a joint venture the conversion plant could be jointly owned.

Marketing Arrangements

Schematically, the biomass-conversion-marketing complex looks like this.



One marketing alternative is the open market. The characteristics of an open market to function well are. . .

(a) There are many producers willing to sell on an uncommitted basis,

(b) There are many buyers,

(c) Both buyers and sellers are informed of market conditions and,

(d) Each is free to act.

Because of biomass bulk and hauling costs we don't anticipate that producers will have access to many buyers. Most producers are apt to have economical access to only one buyer. Because of this, and because of the high cost of conversion plants, we foresee either a contract or ownership integrated marketing system for the majority of biomass.

Thus, some spot or open market acquisition of biomass by plants may occur, especially for crop residues, but establishing a conversion plant on this type of acquisition is highly unlikely.

Cooperative: -- In a cooperative all the stages would be integrated through ownership, with a marketing agreement between the producer and the conversion plant. The cooperative would also utilize time and quality pools. This would result in all producer-members being paid the same price for similar kind and quality of delivered biomass during any given pool period. In a cooperative there would not be an explicit price at the stage of transferring biomass from farm to conversion plant. Rather, members would be paid a derived price -- the gross receipt from the sale of generated products, minus the cost of owning and operating the conversion plant, transportation, marketing, etc. While cooperative members will be paid an advance at time of biomass delivery, full settlement could lag by months or even one year. The cooperative would directly market the finished product on a spot or forward (supply) contract basis.

Several large petroleum cooperatives now exist that have the marketing capacity for fuel generated from biomass conversion. They are especially adept in the agricultural market.

Regular Corporation: -- In a regular corporation the transfer of biomass to the conversion plant would be accomplished through contracts. The conversion plant would vertically coordinate the biomass into the system through forward contracts. There would be written agreements between farmers and ranchers and a conversion plant regarding the delivery and acceptance of biomass at some future date.

Three kinds of contracts are available based on the pricing policy used:

(a) Fixed price

(b) Formula

(c) Participation

In fixed price contracts the price of biomass is established at the time the producer and plant enters into the contract. The price is known to producers before delivery of biomass, thus price risk is shifted to the plant. The title to the biomass is transferred from producer to plant at time of delivery and subsequent price movement of generated products is not reflected to biomass producers.

In formula pricing the biomass price is set after the contract is signed. While the exact price is not agreed upon at the time of signing, the basis for deriving the price is. The formula may reflect one or more market factors in the spot market, futures market, other contract markets, cost of production or plant food value of biomass if it remains on the farm. Formula pricing has been used in milk, eggs, grain, livestock and cotton contracting. While fixed contracts have explicit prices, formula contracts have lag prices.

The third type of contract for transferring biomass from producer to plant is participation. In a participation contract the producer participates in the selling price of the finished product. Participation and formula contracts differ in that the producer's price in a participation contract is based on the market price of the product generated from the biomass he delivered. Another way to say this, is that it is based on the price of the conversion plant output. Producer prices in formula contracts are less directly related to product price. Participation is lag and implicit pricing for biomass. Although suppliers of biomass with participation contracts may not be structured into pools as with cooperative marketing agreements, their price is similar to a pool price. In participation contracts there is usually an agreement between the producer and the plant on the costs for processing, transportation, selling, etc., that is deducted from the selling price of the finished product in order to arrive at the producer's price.

Joint ventures are business arrangements between two or more participants organized to conduct marketing operations or enterprise together. Firm identities in a joint venture remain separate. In the biomass industry, a fuel or chemical marketing firm could joint venture with an organized group of producers in the ownership of an area conversion plant. The participants would share -- on some agreed basis -- expenses, profits, losses, risk, and management control over the conduct of the joint venture.

If the biomass conversion technology leads to area centered plants, the most likely critical problems to be encountered are:

(a) Unwillingness of producers to sell crop residues or to produce crops specifically for fuel and chemical conversion,

(b) Contracts that favor one party or the other,

(c) Lack of predictable contract performance, and

(d) The economical feasibility of the business to either producers or converters or both.

Converting plants will not be successful if they offer contracts to farmers on a take-it-or-leave-it basis. When it is all said and done the most feasible marketing system may well center on the shortage and high cost of fuel to farmers. Then producers would provide biomass in order to obtain fuel and chemicals to continue farming.

PANEL DISCUSSION OF FIRST DAY'S PROCEEDINGS

CHAIRMAN: Mr. Morton Sosland, Editor and Publisher, Milling and Baking News

PANEL MEMBERS: Mr. David Stroud, President
National Livestock and Meat Board

Mr. Willard C. Theis, President
Senon-Shields-Theis Grain Company

Dr. Russell Lorenz, Director
Northern Great Plains Research Center, USDA

Dr. Davis Ward, Head of Research and Development
Office of the Secretary of Agriculture

Dr. Buell Beadle
Former Director of Research and Development at
Farmland Industries

MR. SOSLAND: My college roommate's kid brother was named Jimmy Schlesinger and if I went to Jimmy and wore a badge that said "Think biomass" I'm sure he would ask me what I was talking about and I'm not sure that I'm enough of an expert to know.

Let me say right off that the economic implications, which I would like to touch on very briefly, of what you all have been considering today are so staggering to me I feel very much like the Greek god, Prometheus, who brought fire to the earth. Carrying some of these suggestions we have heard today to their full extremes it seems to me would have a more monumental impact for the future of our economy and for the future of the world's economy than any of us can possibly imagine. I believe that the consideration of this whole issue of reducing our grain export availability in order to create biomass would create grave consequences. If anyone in Japan, a nation whom we have encouraged to build their whole economy on the thought that we would supply them with food, even thought we were seriously considering reducing exports, then I think World War III would start very quickly. At least if I were the Japanese government I would be making plans to begin it right now. Even a 25% reduction in exports would have profound effects on other countries. There is no way the U.S. can reduce exports by 25% without deciding who in the world is going to eat and who in the world is not going to eat. In fact, if we were to reduce exports by 25%, the demand for crops would increase so much that we would not be able to continue export reduction, because I think people will pay a higher price for food than they will pay for energy.

A great deal of the world has existed with a minimum supply of energy. It's the developed lands where people have not really had to make that choice between food and fuel. But if a biomass project forces upon us the choice, between food and fuel, there is no question in my mind that the decision would definitely be in favor of an adequate food supply. I don't think biomass at $40 a ton will ever compete with agricultural food uses of crops. At least I cannot conceive of that happening.

The second point I would want to make is this, injecting into the agricultural economy the possibility that a biomass program would somehow multiply the value of crop production and the value of cropland is a concept that I think needs to be considered. Carried to some extreme we would have a repeat of the period we had in '72, '73 and '74 when the thought was not too far from some people's minds of plowing up housing subdivisions to plant soybeans.

The adjustment that would be required in federal price support programs in response to a large federal investment in the biomass project is also something that has to be considered. Congress is about to go through a terrible procedure in deciding what kind of price supports for crops that we should have. Secretary of Agriculture Bergland, has now proposed that we enter into some kind of cartel arrangement on wheat pricing. Such an arrangement won't work, but that is an alternative. Believe me, politicians would seize upon biomass an as alternative if the scientists presented it to them as a possible alternative.

It seems to me, one who believes in trade, that the alternative we have not thought of in here is a possibility of so increasing the rest of the world's reliance upon us for food that in effect we would encourage other countries to devote their lands to the production of biomass or else devote themselves to the reduction of fuel. We in the United States can raise grain better than any other country can. I'm not sure we can raise biomass.

I have come to the conslusion that a lot of the parts of the world where there is heavy rainfall and different kinds of land are probably better equipped to create a biomass fuel source than we are in this country. The Midwest raises grain better than anything else and I would hate to see us fooling with our existing crop production system.

MR. STROUD: Mr. Sosland, I would agree with you. You have touched on the export market particularly. I think we would see considerable resistance from the livestock sector to the implementation of a biomass program, particularly in the early stages of developing the program prior to any levels of a massive biomass education. This sector of agriculture would view the production of biomass in terms of its competition with production of pastures and grazing lands and perhaps even other forages that the livestock sector requires in order to continue to stay in business.

In making that statement, though, I am impressed with the fact that MRI and other people who have worked in the study, have not made willy-nilly suggestions that are bound to impinge on other people's endeavors. Advocates of points of view these days are wont to do that sort of thing. As I listened to the conference speakers, I heard allowances and I heard warnings and I heard suggestions that biomass production is something that needs the attention and consideration of all the different agricultural enterprises. That pleases me very much.

It may surprise some of you to have the chief executive officer of the National Livestock and Meat Board say that we are trying to make the people involved in livestock production understand that it is not written in the scriptures that man shall produce livestock and make a profit therefrom, always, at all times. Yet my job is to try and enhance the factors in the consumer marketplace that will assure that the industry is able to produce livestock at a profit. The meat industry is going to have to take into consideration that there are indeed food shortage problems, calorie shortage problems, protein shortage problems, other vitamin and mineral shortage problems around the world. And I'm not sure that the livestock and meat industry has fully taken these factors into consideration. I don't think that every farmer really understands the current situation and I want every farmer to understand it. We will be better able to compete with the problems we are going to have in the marketplace over the next several years if these facts are understood.

And so I think that forces operating against the livestock and meat industry's hope and dream and perhaps right to grow and sell an animal product for the American and foreign marketplace are going to be pushing harder and harder for substitution of those animal products by vegetable products. We have already seen some stupid statements coming out of the Senate Select Committee on Nutrition and Human Needs in the last several weeks. The statements are based on stupid analyses of situations and the staff group of the Senate Select Committee has absorbed these analyses and put out as gospel what it thought it read in the scriptures.

<u>MR. SOSLAND</u>: David, can I say for the milling and baking part of the industry, we don't agree?

<u>MR. STROUD</u>: Well, but perhaps you do agree, because we are not against a vegetable diet. A nut-grain-legume diet would provide enough protein for a human. Also a diet of nine slices of bread and a quarter cup of peanut butter and 2-1/2 cups of spaghetti and a quarter of a cup of English walnuts would give you a pretty good protein balance for about 1,650 calories a day. If you wanted to switch over to a fruit and vegetable diet, you could get about the same amount of protein as that by eating about 13 lb of fruit and vegetables and you would consume about 6,000 calories. But if you would

rather just take a 7-oz beefburger and two glasses of skim milk for 540 calories, you would have the same protein balance. This is where some of these problems are.

I want to express that I think there are very strong and reasonable forces working to limit meat consumption in the United States and elsewhere. If limiting meat consumption gains acceptance, vacuums of information on vegetables will be created which could be filled by information supplied by the biomass people.

MR. THEIS: Well, I'm kind of a new boy in school. I'm not a scientist, I'm not an economist, I'm not a researcher. I was late to your meeting. I walked in just as I was being legislated out of business. You are going to cut off the exports. I can no longer sell feed grains to the feeders, to the feed lots. Now I'm excited. I have got to find a way to exist.

Let me speak just a minute to the subject matter that the professor from A & M was talking to you all about, marketing. I guess that would by my long suit here. You are going to have to develop this biomass, you are going to have to develop the tonnage, and also you are going to have to develop the end use of it. And we are going to be the handling parties, I guess, or the marketing arm.

There are three ways that you can get into biomass. The first way was mentioned by the professor from A & M. This way would be to sell biomass on what we call an identity to preserve basis which is a contractual basis between the producer of biomass and the user of biomass. We, the marketing industry, would handle it through our system of grain elevators, warehouses, and such, but we would handle it as "identity to preserve."

The second way that you could handle the marketing of biomass would be on a contractural basis such as the way that popcorn is contracted today. The popcorn processors come to the industry and ask us to go out to the producers in our area and make up production contracts. We make up these contracts on an acreage basis, not on a tonnage basis, and then we handle it through from there. We use a margin of profit for our area of service, which is handling, storage and distribution.

There is a third way you can handle the marketing of biomass. Let's assume that you have done a fine job and we have got biomass coming out of our ears and we have got to have a way to handle it on a competitive marketing basis. There are a lot of demands involved in this marketing. Not only have you got biomass all built up and growing in one place, but you have got a guy just begging for the biomass in another place. So our marketing system comes into function hopefully as a free market and we then have a price mechanism that gets into operation and levels out the supply and demand of the biomass. There are many factors that must be taken into consideration in this type of marketing. You just can't develop it overnight.

In my estimation, you are going to have to bring about some way of conducting this business within the laws of the land. You are going to have to develop and apply trade rules. You can't simply start trading. You are going to have to have trade rules, you are going to have to have an understanding, you are going to have to have an arbitration system, you are going to have to have some means of an appeal system to the arbitration, you are going to have to promote, protect and improve a nationwide system of grading and evaluation of biomass. But particularly you are going to have to prevent undue government intervention into the free enterprise system, particularly as might apply to the biomass market system.

DR. LORENZ: I'm in the agricultural production research profession. For those of you who don't know where the Northern Great Plains Research Center is, It is at Mandan, North Dakota. I have been there for all of my research career working on the forage and range research project. The first 20 years I was part of a team that was based in the 17 western states known as the arid pasture and range research unit. With the reorganization in 1972, they changed some boundaries and suddenly I went from being the most humid of the arid to the most arid of the humid.

There are some areas of the country where levels of production may be high enough to justify biomass production for energy conversion with technology that we now have. As time goes by, technology may improve in production, in conversion, in transportation, and in everything else involved to expand these areas. But based on my experience in the western part of the United States, I believe that for biomass production the old cow out there roaming around gathering up the biomass is a darned efficient harvester. Times may change and circumstances may change, but at the present time I don't believe there are many possibilities for biomass conversions in much of the West. There may be some unique situations. I don't want to put a paint brush application to this, but there may be some unique situations where it can be worked out with present technology.

I think one of the things that we have to keep in mind is what trade-offs might be necessary in this whole energy business. It looks to me as though we have got food production and energy production coming head-on.

Being in production research for the last 25, 26 years, we went through a cycle where production research was a mighty bad work and some of our budgets from that time showed it, too. The thing that has to be remembered in agricultural research is that you don't come up with answers overnight. And one of the main stems of our agricultural production has been some of the long-term research carried on by state universities, by the agricultural research service of USDA, of which I am a part, and other groups who have carried on long-term research.

On a short-term basis you can solve some problems rather quickly. But when you are working with biological systems out in their natural realm, like we are with crop plants, forage and range material, and anything else grown, it takes time. It takes time to get answers that are reliable.

And this leads to another thought that I have had in listening to the deliberations today. We can make a lot of predictions based on past history of production, but we have to remember that those are averages, they are based on probabilities. We can extrapolate those to another period of years in the future, but on a year-to-year basis we have to live with the production for a current year. This is what has the hay supply, the straw supply and the spring grazing supply in much of the northern plains, as well as a lot of the rest of the country, in rather dire straits for this coming spring. Right now in North and South Dakota you would be hard put to buy a ton of straw. Nobody is parting with it if they have any.

So these are some of the things from the production standpoint that we have to think about. I believe that the program as put together for this session has covered some very basic and some very important aspects of the problem. I think that from this point on we need to all think carefully about what the alternatives are, what some of the upcoming problems are going to be. I think society in general is becoming more aware of what we may be facing in the way of food and energy shortages in the years to come.

The energy situation is one of the areas where people who understand the situation need to inform the public. I don't imagine there are any of you that live in neighborhoods that are any different than mine and that is that any time of the day or night you might hear a 450 cubic engine wind up a pair of foot-wide tires and leave a cloud over two black strips. You have to drive several hundred miles at 55 miles an hour to save enough fuel to let him do that once. We haven't got people convinced that there's a problem.

Now, when you come to the alternatives and you start swapping food for energy, it's kind of like coming at the public with a 2 x 4 between the eyes. And that might make some sense. So I think sessions like this where we discuss biomass as an energy alternative can probably be of some benefit in the end.

DR. WARD: I have some 3D comments. That does not mean they will be easy to perceive. That means they are disparate, disruptive, and disjointed. I have made some notes as we went and that's the order in which you are going to get them.

Those that manage the soil and water and genetic resources across our countryside, call it agriculture and forestry, have in the past incorporated soybeans, sorghum, sunflowers into their practices and systems. So on the basis of our past history, I think we can assume that some adjustments can be and will be made in current agricultural practices to enable us to derive energy from biomass for use not only in agriculture but outside of it.

If we are to change current agricultural practices to enable us to produce biomass we first need to define objectives. What is the biomass for? Is it for use within the food fiber and forest product systems or for use by industry, homes, and so on? This question was alluded to in today's talks. I think it's a very significant question.

You will recall Dr. Moss's comment as he was explaining some of the results of his research. He had a problem in carrying out some of his activities. At one point in his research he couldn't work on the land due to rain. That situation reflects the climatic, biological and economic uncertainties that we deal with in any agricultural endeavor and these unpredictable factors are going to affect biomass production just as they do any other kind of commodity production.

I wondered about some of the references in the speeches to energy requirements as related to nutrient needs. Do plants that yield more biomass relative to others require more nitrogen and phosphorus? And, if so, what's the balance? If plants that yield more biomass do need more agri-chemical then they would require more petroleum from which to derive the nitrogen or other chemicals.

Changing the vegetation and management of marginal land may also raise some environmental quality questions. I want to emphasize that we live in a one-vote, largely urban society and that matters of impact on wildlife, water cycle, and so on, are significant issues today. These impact matters would be a part of the mix in the decision-making process of biomass production on a national scale.

Modern scientific literature includes lots of references to recombinant DNA research, i.e., the transfer from one organism to another of highly selected pieces of genetic material that introduce into one of the organisms a trait that's desired. What are the implications of this over the long pull for something such as biomass? Its implications for food and wood products are in the same vein, I think.

There are things that we foresee on the horizon that will significantly influence our capacity to produce food and perhaps our capacity to produce biomass.

We have heard reference to the ramifications for foreign policy, trade, defense, and humanitarian aspects. We quickly talk about the role of food sales and maintaining a balance of payments that allows us to purchase foreign petroleum. Yesterday, I was among a group in the State Department talking about an international scientific conference for 1979 about science and technology for development. And there was constant reference to the group of 77. The group of 77 are the 77 underdeveloped nations that have their minds set on doing some things about world economy. Our approach to some of these issues, such as whether or not we sell grain for use for human food, will be markedly influenced by these kinds of considerations. Those small countries are important to us in a political sense. They are places from which we get important minerals and other things that we require for our society.

There is a question of competition for water. We have already heard about the water table. There are urban and industrial demands on water. There are very large questions about water requirements for energy production and processing. How does this fit this whole biomass question? It's clearly a significant part of the picture.

I guess I have said that agriculture is both a highly intensive energy user as well as a potential energy producer. Now, the forest products industries are about 46% energy self-sufficient and research is moving toward significantly increasing that percentage. I have the impression that our food processing industries are highly dependent right now on natural gas and that there are serious questions about the continuing supply of that gas. Now, it's of vital importance to us as consumers that we have these products processed and it's almost of equal importance to the producer because that's part of having a market for their product.

So I think we need to raise the question, what about the use of agriculturally derived material by the processing industry in order that the materials continue to be processed?

I get on the stump a little bit, I suppose, in terms of the nature of what my business is about, the planning and coordination of agriculture research. I think today has emphasized what we should all have known, that there is a wealth of know-how in agriculture science regarding processing, marketing and recycling technology of things produced from the land.

There is a new element in the research administrator's priorities of things to consider and that is the matter of using soil, water and particularly genetic resources as well as organic residues to yield energy. Now, we have had a long history of developing the concept within the agricultural research community. There was and still is a basic underlying theme to provide ample supplies of nutritious food, natural fiber and wood products of high quality at reasonable costs to consumers and with appropriate returns to producers, processors and marketers.

Now, what I think we hear today is that we may be adding a new dimension to that basic charge and responsibility of agriculture science and that's to add the word "energy." Now, included in this has been the conservation of natural resources needed to meet the objective just cited. I don't think we can produce biomass or any other commodity at the price of these natural resources. We don't want to deplete our resources for biomass any more than we do for food. I also think we should consider recreation, wildlife habitat and wilderness preservation. Remember this large, urbanized society attaches great significance to these things. They are significant parts of what the research administrator has to take into account in figuring his objectives and priorities.

And lastly I would make reference to rural communities and people development. There hasn't been a whole lot said about that today. We need to consider the effects of biomass production on economic systems in the rural communities and the people in these communities. These economic situations need to be taken into account if we take any steps that will significantly modify our patterns of managing our agriculture.

I haven't heard any advocates at this conference, but there are those who suggest a less energy-intensive agriculture. If we put this into our mix, we have the result that if we are not using machines which are major consumers of our energy, then we must be considering using human labor and draft animals. And where will they come from? And then if we really throw draft animals back into the mix in any significant way, what part of our acreage are we going to need for animal feed?

I also wanted to comment on contractual arrangements of biomass production. It looks to me like there are implications for the freedom of individual producers in decision-making. I believe there are each time we take those steps. There might be built into that some trends toward corporate farming, which I will tell you from firsthand experience, the Congress of the United States as a whole finds horrendous. Corporate farming is just a terrible thing to deal with. It's the small farmer with which we are principally concerned.

It seems to me that a question about the insurability of producers will come up if biomass becomes an agricultural commodity. There are implications for farm legislation, I believe. We now talk about floor prices for some of our commodities and the underlying concept, I think, is to insure that our farmers don't get in the position where they don't have an adequate income. So are we going to add biomass as a component for that legislation?

DR. BEADLE: My experience is research from a business point of view. Over the years I have developed a viewpoint that any suggested project will fail if it isn't economic and it was from this viewpoint that I listened to the various papers. They seemed to be research, but if they are not economic they won't succeed.

We do have a problem, however, in the fact that 80% of our petroleum reserves will be used up in less than 50 years. We do have a problem in the fact that half of our natural gas will be gone in about 8 years, as nearly as we can predict. And we do have the problem that the farmer is the only one using solar energy and he uses only a very little bit of that. And when you look at these energy production materials or biomass, they are an indurect use of solar energy. We have a problem of natural gas for fertilizer manufacture.

And so in looking at this, it seems to me that we need to consider all of these things in terms of economics, because if they aren't economic, they won't succeed. So having said that I will go on.

Agriculture produces an annually renewable supply of material. We have marginal lands, we have undeveloped lands, we have forest lands. I'm told that there are trees that will mature on a 6-year basis. I can visualize, then, that there might be 5 or 10 acres here, there and everywhere where certain types of trees would be used for cellulose production, maybe even for wood for that farmer. Instead of having the gas come to him through a pipe, he would raise his own wood.

I can see, and I was particularly interested in the comments about the cattails this morning, because it always looked to me as if those darned things grow where nothing else will. So I think we should look at things that will use solar energy indirectly where our normal crops don't fit. That was what interested me about Dr. Moss's discussion of the cattails.

Weeds grow everywhere and I wonder if people have looked at those as a cash crop, their feed value and so on. And I wonder how many weeds we may be passing up as cash crop producers, not at the expense of feed, not at the expense of wheat, but in places where production is marginal. And that was the one thing that I didn't hear about today.

Now, we need a lot of research to investigate this major problem regarding energy and how biomass production could aid in the solution. One of the things that we need to do is to convince the American public that there is an energy problem. Because the energy problem is here and will stay with us. I have seen and you have seen a lot of sawdust lost, a lot of wood clippings lost or burned out in the open, and these were grown on land.

And so in short, then, I think that we need to consider the use of marginal lands or fallow lands as a possible solution for the energy problem because I don't believe that any program of substituting weeds or trees or what-have-you in a wheat field is going to get very much consideration by the farmer. I don't believe that if you suggest to him not growing his corn on a certain acreage and using it for growing biomass that he will act on your suggestion. You will have to do a lot of economic demonstration before these landholders will agree to devote some land to biomass production.

But in the background is this energy problem. I was reminded that 20 or 25 years ago a medical doctor brought me a brown paper bag and he wanted me to find out what the fat content was of the material in it. I looked in the bag and it was material I had never seen before and I said, "What is it?" He said, "Well, it is something called safflower. I think it's going to be a major crop one of these days and I have been growing a little of it and I would like to know hot it analyzes chemically." Well, you all know what has happened to safflower since then.

So in that context, I'm glad to see some attention being given to the energy problem and how agriculture may aid in its solution.

MR. STROUD: Dr. Beadle, I agree with you that somebody may decide that we are going to start growing weeds and roots in the middle of wheatfields and cornfields. That bothers me a bit.

In his speech, Bill Black, set up a pretty good series of models or alternatives for an economic enterprise. And then Mr. Hudson told us what The Anderson's have done with corn cobs and I simply don't see as much of a problem in marketing as I thought I heard you, Mr. Theis, setting up. I think the corn cob process sounds like a pretty good entrepreneurial start-up to me. Many of the problems that anybody else would face were overcome. Do you see more problems then?

MR. THEIS: No, we don't see any problems if it is developed, regulated and promulgated on a reasonable basis of where it can be handled, by one of the three marketing systems, by "identity to preserve," contract, or open free market. There is no problem in handling it. Go ahead and develop it. Get the people to use it. We will be the middle man. And I don't mean that lightly. I mean that we will be in there to process it. It's going to have to be pelletized, it's going to have to be handled, it's going to have to be stored, it's going to have to be distributed. There are many, many facets in the areas that we work in that would fall right in place with this as a known commodity.

MR. STROUD: Then I did misunderstand what you said, because I agree completely with that.

MR. BENSON: I would like to open the discussion up to questions from the audience.

QUESTION: I would like to run back over the kenaf yield data a little bit. As I understand, we are taking somewhere between 2 and 15 tons per acre dry weight, is that right?

DR. ALLEN: Yes, I would like to answer that one. Referring to USDA Bulletin Number 13, that is where all our data came from.

QUESTION: Okay. I have a friend who had the interesting experience of working on a kenaf farm in Louisiana. It was a demonstration for a major paper company. They got in the upper range of the yield the first year, that is, they were over 10 tons. The second year the yield went down and by the third year the nematodes had eaten almost all of the kenaf.

I would like to address this question to Dwight Miller. You people have been working on trying to get around the nematode problem. Could you perhaps say something about that?

MR. MILLER: First of all, the area that was shown where kenaf would grow or might grow was much too broad. It will grow there but in no way will kenaf compete with, say, corn and soybeans in the midwest unless it's on strip mined land where you can't grow corn anyway. Therefore, the region where you said kenaf would grow I'm sure is in error because it would not be commercially feasible to do so. There is no way you could think of kenaf being grown there.

In reply to the question, the Department of Agriculture at its station in Savannah, Georgia, has already developed a strain of kenaf-roselle mixtures which is nematode resistant and apparently so nematode resistant that they tell us that we should not be concerned about a nematode problem with kenaf in the future. In other words, kenaf can be grown commerically and can be a commercial crop where it is economical to do so.

I would also like to mention quayule, because I was surprised to fine that Arizona, where some people are considering planting quayule in the United States, was not on your map. In fact, there is under consideration something like a 10,000-acre area there right now.

DR. ALLEN: I'm sorry, Mr. Miller, I didn't have that information available. I am certainly glad to include it.

The Great Bend area of Texas and California was where the majority of the prime area for guayule was located at that time. Now, there wasn't any grown in Arizona in those early war and postwar planting dates and I based most of my information on the areas that they had selected at that time. And if there is new information that has come up about it, I'm sorry I didn't include it.

MR. MILLER: But to go back to kenaf, I would just like to close by saying that as far as I know Dr. Lipinsky was correct, that the kenaf that had been grown in the United States had been taken over and ruined by nematodes. But at the present time the agronomists at the Savannah station insist that they have developed a kenaf strain that will not have a nematode problem.

QUESTION: I address this question to Dr. Ward. I'm reacting to the suggestion Mr. Sosland made that we become the breadbasket of the world, let everybody rely on us for their food and we in turn can then rely on them for energy. Is this something that you think would be politically stable?

DR. WARD: My view is that it would not be politically stable.

MR. STROUD: Mr. Butz felt very strongly that this type of balance of trade was a possibility and I don't think he got a lot of support for that position in the department. I supported it because I didn't know much about it and I like Earl Butz.

DR. WARD: The other side of the coin is that in a significant measure that is a fact already.

MR. STROUD: That we are, in fact, trading a whale of a lot of food for energy right now?

DR. WARD: Yes, but it's not an advocated policy.

MR. THEIS: No, but that is the greater percent of our balance of payments, our export agreements with the offset of the cost of petroleum. That's a fact today.

MR. STROUD: I hear the question to be, "Could it be policy or should it not be policy to use food sales abroad as a clout, as a club, as a political policy of the United States." Is that the question you are asking or the statement you are making? Because it is not now. As Dr. Ward said, it's kind of unspoken.

QUESTION: What I hear is a contradiction which says on the one hand Japan will never stand still for a minor adjustment in our exports and on the other hand a recommendation that we put every nation in the world at our mercy so they will all be like Japan, and I'm saying to myself if they have got any sense they are not about to stand still for that.

DR. WARD: My comment is that that kind of thing is not politically sound, nor is it a stated policy in this country nor ever will be. There are some practical sides of the thing, though, that we will use to our advantage, I think. One such thing is our capacity to produce things that other people need in terms of getting things back that we need. And I don't know why everyone else isn't doing that same thing. I believe they are.

QUESTION: I don't thing we should forget that it isn't just energy and food that we are talking about when we talk of the 77 third country or third world countries. Before long our own mineral resources, some of which are already depleted, are going to force us, even if we produce all of our energy, to deal with these other countries and policitally we will have to deal on that basis.

DR. WARD: I think our moral attitudes, too, require us to do that.

MR. STROUD: Morality and uranium, that will do it right there.

I would like, with your permission, Mr. Chairman, to make a wrap-up statement, not for the panel or the day, but for a very important point of view for the livestock industry of the United States, which at the moment is agriculture's most important producer.

Dr. Lorenz, I heard you talking about the cow as a ruminant converter and its efficiency, and it's absolutely unquestioned that with an extraordinarily low labor input and almost no energy input the cow and her offspring can turn photosynthesis into protein, into iron, into zinc, into selenium and into B-12 and all the other vitamins and minerals and good things that beef and the other meats have. But there is such a push, and at the moment it's a lot of talk, but I see policies being made in this country and in others to move into a more vegetable-based diet. I think that the excitement about biomass could push that a little further. To reduce the nutrients of animal origin that are consumed in the U.S. in particular to similar nutrients of vegetable origin would require about two times the input from vegetables that we get from meat and would require a substantial portion of the grain crop. There's no doubt about that.

But the animal protein has twice the value of plant protein. Of course, it's better protein to begin with. And to provide a nutritionally adequate diet just from vegetables would be difficult to achieve on an educational basis alone; it would be impossible. I think one of our panelists touched on that, too, to educate the American people.

But we simply cannot forget, either, the pig. The nonruminant pig in the face of this challenge is going to be having a problem, I think, if we make this move. We will kill somewhere around 75 million pigs, I suppose, in some 365-day period this year. That's going to be not simply all of the meat that comes from it and all the hides and all the hooves and all the gelatin and all the hog bristles, but it's going to be 75 million pituitary glands and it's going to be 75 million phials or however many phials of heparin you get out of that and it's going to mean lives of a whale of a lot of diabetics saved in the United States just from the cattle and hog slaughter. And these things are constantly set aside or not observed or forgotten or, worse, irresponsibly cast aside when many, many people start discussing the American diet and try to make me feel guilty about promoting it and try to make you feel guilty about eating it. I think there are some more things that have to be discussed.

DR. WARD: I quit speaking earlier because I decided I had used too much time. But my straight-from-the-shoulder comment is that the relative emphasis that I heard today on marginal lands reflected in part to me a sense of difficulties in approaching nonmarginal lands because of the political implications of that. And so the marginal lands to me got relatively an undue empahsis and I regret that.

What all this also indicates indirectly that somehow or other animal aspects of food production may be lower on the totem pole in terms of priorities than the possibilities of biomass production. I don't know that I want to get in the position of subscribing to everything Mr. Stroud says, but there's food for thought in that idea.

CORN PRODUCTION PRACTICES

Dr. T. A. McClure

Battelle Columbus Laboratories

I would like to talk about the agricultural production and cost aspects of corn as a potential biomass crop. My presentation will be a very brief summary of the section of Batelle's biomass report entitled "A Systems Study from Sugar Crops and Corn."

The major topics of discussion include (1) an overview of U.S. corn production, (2) presentation of agricultural aspects of various alternatives of using corn as an energy feedstock, and (3) a rough assessment of the energy balance of theoretical energy output-input ratios associated with U.S corn production.

Corn for all purposes was harvested on an annual average of 79 million acres between 1974 and 1976. Eighty-six percent of this land was used to produce grain and 13% was used to produce silage.

Grain yield between 1974 and 1976 averaged 82 bushels per acre for the entire United States with an average annual total production of approximately 5.6 billion bushels. The leading corn grain producing states include Iowa, Illinois, Indiana, and Nebraska, and together these states contribute about 60% of all U.S. corn grain production.

This map in Figure 1 indicates the location of corn grain production in 1969. Note that the area harvested in 1969 was only about 53 million acres compared with over 71 million acres harvested this past year in 1976. However, there has been relatively little change in the location of corn grain production insofar as I can tell during the past 7 years, so I really do not think the production pattern indicated on this map would be changed to any significant degree.

The average U.S. corn silage yield was 10.8 tons per acre, and this on a fresh weight basis between 1974 and 1976. This was not dry weight. Production of silage is more spread out than corn grain and only 36% of the total production of corn silage was accounted by four leading states of Wisconsin, Iowa, Minnesota and New York. Total annual production of silage ranged from 110 to 116 million tons from 1974 to 1976. And again I want to emphasize that these yields of production are for silage as it goes into the silo, which is at a moisture content of about 65%.

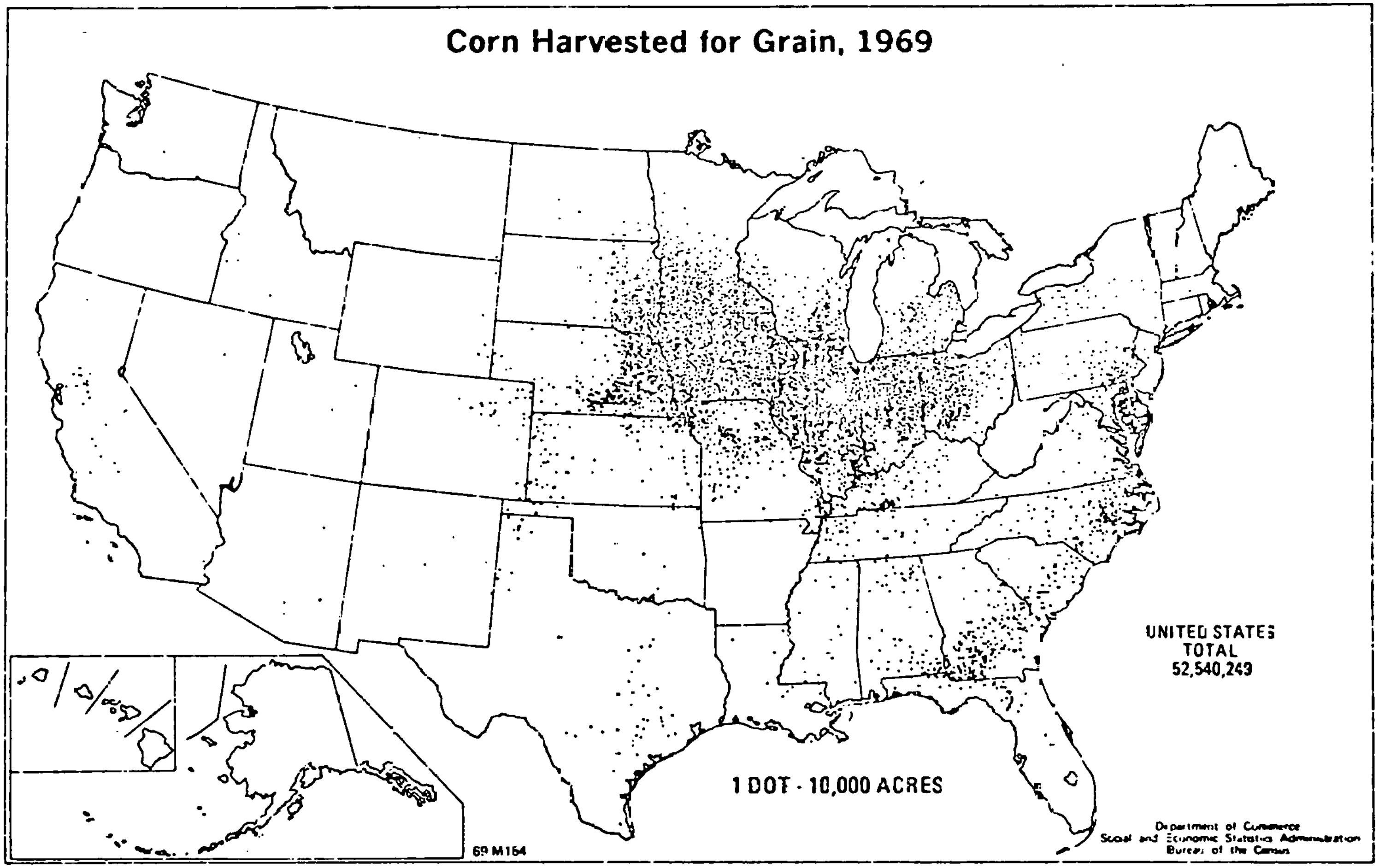

Corn Harvested for Grain, 1969
UNITED STATES
TOTAL
52,540,243
1 DOT - 10,000 ACRES
69 M164
Department of Commerce
Social and Economic Statistics Administration
Bureau of the Census

Figure 1

There are four other states that do not contribute a large volume of either grain or silage. However, they do obtain higher than average yields. These states are California, Washington, Texas and Colorado. The average yield for these states between 1973 and 1975 was 99.3 bushels per acre. And it should be noted that these yields are achieved under irrigated conditions. In some of the midwest cornbelt states, such as Illinois, there are certain years when they, of course, have gotten average state yields well over 100 bushels per acre.

If you just do a very simple extrapolation of past trends over the past 25 years and look at some of the corn performance tests in various states, the average cornbelt yields (principally in Illinois and Iowa) might approach the neighborhood of 150 to 160 bushels per acre by the year 2000, which would be approximately an annual average growth rate of about 2.3% per year. Silage yields might reach 18 tons per acre. However, these projections are based on the assumption that the good crop weather that the U.S. has enjoyed over the past 20 or 30 years will continue. However, I think there are some indications that weather patterns might be changing and that crop growing conditions may not be as favorable as we have been experiencing.

We looked at three alternatives for using corn as an energy or industrial feedstock. These include first, using silage to produce substitute natural gas, second, using corn grain to produce ethyl alcohol, and third, using the crop residues after the grain has been taken off to produce either substitute natural gas or ammonia. We might also produce, I believe, furfural as well.

Th investigation of these three alternatives required that we determine (1) the estimated cost of producing corn grain silage and residues in selected regions of the United States, (2) the density of production in these regions, (3) the costs associated with collecting and delivering the corn biomass to a processing facility, and (4) the value of corn silage and corn residues as a feedstock when weighed against its value as a feed ingredient.

An important point I want to emphasize is that whether or not the grain silage or residues is ever used as an energy feedstock depends on the price that energy producers are willing to pay and that price will certainly at the very minimum have to equal the price commanded in the conventional feed and food uses for corn. However, as anyone familiar with agriculture knows, the commodity market prices can vary tremendously over a short period of time and, therefore, our analysis is based on estimated production costs plus some return to management in order to derive the approximate price that energy and chemical producers might have to pay for corn biomass as a feedstock material.

Our first alternative was to use corn silage to produce substitute natural gas. Silage is grown in all mainland states from a low of around 3,000 acres in Nevada up to over a million acres in South Dakota. Average yields on a fresh weight basis range from about 5 tons per acre in the Dakotas up to approximately 20 tons per acre in irrigated areas such as the Pacific coast. The dry matter content of silage varies between 30 and 35%, which means that dry biomass production per acre runs between 1.7 and / tons. Now, under optimum conditions and very high yields a maximum of perhaps 8 to 10 dry tons of dry corn plant biomass can be produced.

Southern Wisconsin, Indiana, the California San Joaquin Valley and the Texas high plans were four regions selected for analysis of corn silage production costs. These regions exemplify the various conditions under which corn silage is produced and the likely range of costs. Also all of the regions are relatively close to supplies of either sewage sludge or manure which would be necessary for the fermentation process in manufacturing substitute natural gas. These regions are not intended to be recommended locations for plants. They are merely intended to indicate some possible variability that might occur in silage production costs. Maybe some other reigons should be examined as well, but for the sake of time and funds we decided to select these four.

Currently the density of production for the four silage region ranges from a high of 78 tons per square mile, this is on a dry basis in Wisconsin, to a low of about 20 tons per square mile in Indiana (see Table 1). Here I want to make the point that our analysis is based on the current pattern of agricultural production in which corn is grown on family farms and not on massive plantations. Although corn could certainly be grown on plantations such as sugarcane is, this would require some fundamental structural changes in mid-western farming practices where corn is conventionally rotated with soybeans, alfalfa and some type of small grain.

At any rate, assuming the current production densities, the average hauling radius one-way distance required to supply approximately 500,000 tons of silage on a dry weight basis to a processing plant varies, between 32 and 63 miles (see Table 1). Now, naturally if your processing plant were to be built using corn silage, production in the area surrounding the plant might increase substantially if the silage price were sufficiently high to earn the grower a reasonable profit.

The costs of producing silage in the four regions as shown in Table 2 varied widely on a per acre basis from about $161 per acre in southern Wisconsin to $428 per acre in Texas. These costs are based on data supplied by the USDA Firm Enterprise Data System of budgets and also from budgets developed by Texas A&M University for the Texas area. Note that the difference of costs among the four regions on a per ton produced

TABLE 1

ESTIMATED DENSITY OF CURRENT CORN SILAGE PRODUCTION, 1973-75 AVERAGES

Region	Dry Basis Production Density,[a] tons/sq. mi.	Hypothetical Area to Supply 500,000 tons, sq. mi.	Average Hauling Radius,[b] miles
Southern Wisconsin	78.3	6,386	32
Indiana	20.2	24,752	63
California San Joaquin Valley	39.7	12,594	44
Texas Panhandle	21.0	23,809	61

(a) Ash-free from silo, after adjustment for storage loss.
(b) Average hauling radius = 0.7 R where R = radius of circle.

TABLE 2

MAJOR COMPONENTS OF ESTIMATED PRODUCTION COSTS FOR CORN SILAGE
BY SELECTED REGION, 1976

	Southwest Wisconsin	Indiana	Texas Panhandle, irrigated	California San Joaquin Valley, irrigated
Yield (Tons/Acre, Fresh Weight)	10	14	24	25
	- - - - - - -	$ Per Acre	- - - - - - -	- - - - - - -
Preharvest Variable Costs	55	70	138	128
Harvest and Hauling Variable Costs	44	79	149	127
Machinery Ownership Costs	18	17	35	30
Land Charge	30	42	72	45[(a)]
Management Charge	14	20	34	21[(a)]
Total ($/Acre)	161	228	428	351
Total ($/Ton)	16.10	16.30	17.80	14.05

(a) After credit adjustment for double-cropping.

basis narrows considerably and after adjusting costs downward for a possible double cropping in California, this region becomes the lowest cost area at around $14 per ton. Although the costs per acre in California under a high level of management-irrigated system are quite high, the yields are also considerably greater than under the nonirrigated conditions.

An important factor in determining the potential value of corn silage as an energy feedstock is its feed value. Under favorable land and climatic conditions there is no other feed crop that will produce more digestible energy per acre than corn silage. One ton of fresh silage is generally said to be worth about one-third its value of the same quantity of alfalfa hay. On this basis the current feed value of silage based on hay prices in these regions ranges from about 2.9¢ per lb in southern Wisconsin up to a high of about 3.8¢ per lb in the San Joaquin Valley (see Table 3). This provides another basis for the estimated price that would have to be paid by the chemical producer utilizing silage as a raw material feedstock.

The second alternative for fuels from biomass might be to utilize corn grain to produce ethyl alcohol. Corn grain is produced in virtually every state ranging from about 10,000 acres in Montana to over 12 million acres in Iowa. Average state yields vary from about 33 bushels per acre in Arizona to over 100 bushels per acre in Illinois. Some growers have recorded yields exceeding 200 bushesl per acre. Corn grain production is reported in 56 lb bushels and, therefore, 100 bushels per acre is equivlent to 2.8 tons of grain. The bushels are reported in terms of a 15-1/2% moisture content so on the dry basis 100 bushel per acre would be equivalent to 2.4 tons per acre.

Four different regions were chosen to exemplify corn grain production costs. These regions are shown on the maps in Figure 2. The Illinois and Iowa regions shown on this map represent typical costs in the Iowa corn belt and the Texas and Nebraska regions represent costs of yields on irrigated land. These regions are as defined within the USDA's Firm Enterprise Data System and Crop Budgets, although the Texas data was, as previously mentioned, developed on budgets developed by Texas A&M University.

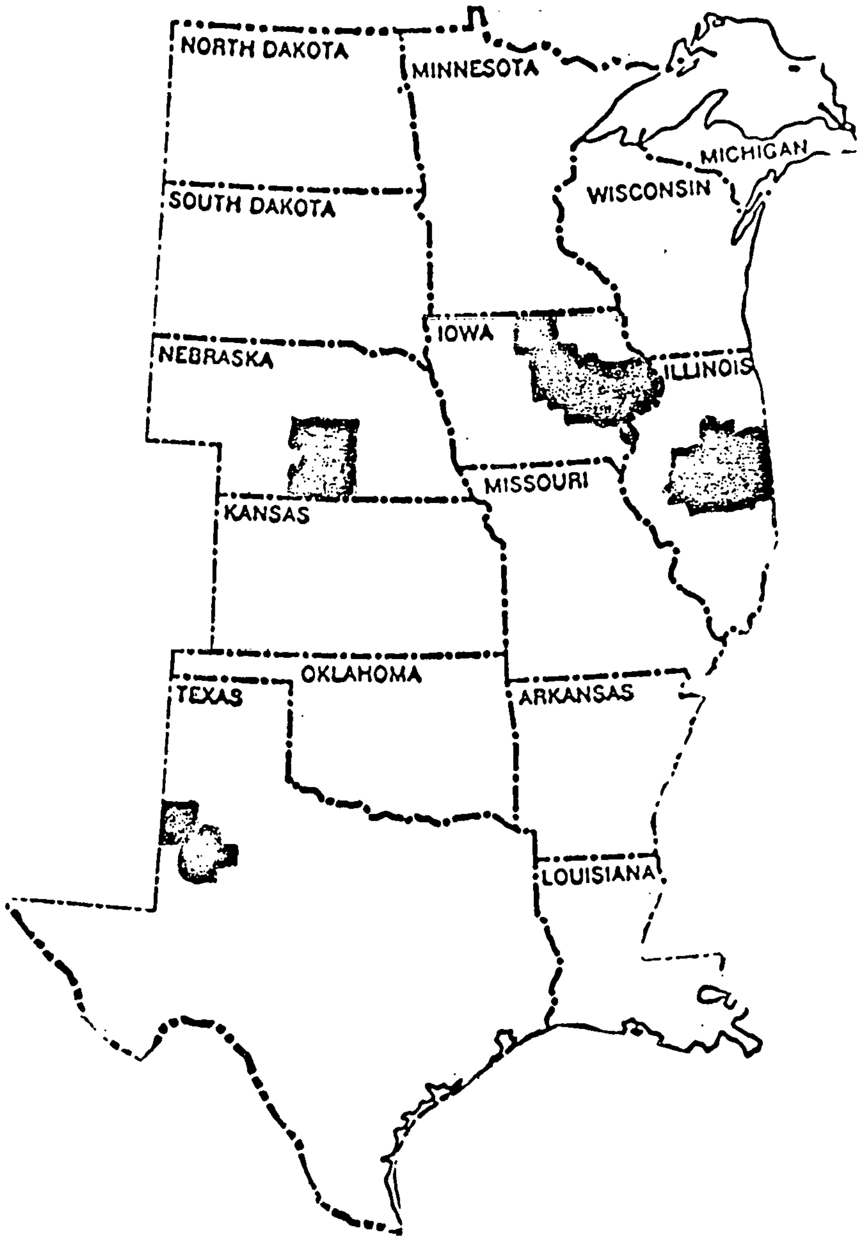
The hypothetical average one-way hauling distance based on the density of production required to supply a million tons per year to an ethyl alcohol facility ranges from about 12 miles in the east central Illinois region to about 58 miles in the Texas panhandle (see Table 4). Again this is based on the current pattern and density of grain production in each of these regions. These figures assume a 100% capture rate of all grain production, which, of course, is unrealistic. I think Mr. Hudson noted

TABLE 3

ESTIMATED YIELD AND DELIVERED COSTS OF CORN SILAGE, PER POUND OF ASH-FREE DRY WEIGHT

Region	Yield/Acre, lbs	Costs/Lb, cents	Estimated Feed Value of Silage,[b] cents
Southwest Wisconsin	5,888	2.72	2.91
Indiana	8,244	2.74	2.91
Texas Panhandle	14,131	3.02	3.13
California San Joaquin Valley[a]	14,720	2.39	3.78

(a) Assumes double-cropping would be practiced.
(b) Estimate based on average 1976 value of alfalfa hay divided by three.



SELECTED REGIONS TO INDICATE CORN GRAIN
PRODUCTIVITY AND PRODUCTION COSTS

Figure 2

TABLE 4

ESTIMATED DENSITY OF CORN GRAIN PRODUCTION
IN SELECTED REGIONS

Region[a]	Production Density,[b] tons/sq. mile	Area Required to Supply 1,000,000 Tons, sq. miles	Hypothetical Average Hauling Radius, miles
East Central Illinois	1046	956	12.3
Central Iowa	896	1,116	13.3
South Central Nebraska	333	3,003	21.9
Texas High Plains	48	20,833	57.6

(a) Estimated square miles in designated areas:

East Central Illinois	16,000
Central Iowa	20,000
South Central Nebraska	11,800
Texas High Plains	8,100.

(b) Grain tonnage at 15.5% moisture content.

yesterday that there are going to be some farmers who are going to bring their corn or the cobs or whatever you are talking about in from close by, but then you will have others that might deliver them from a much further radius. But anyhow, our figures provide at least an initial estimate of minimum hauling distance.

It was interesting to note that based on the USDA Crop Budgets for each of these regions that south central Nebraska was the least expensive area to produce corn both on a per acre and a per ton basis, and this is somewhat surprising. I think it is based on the average yield reported for this year. Iowa has the highest cost per ton basis. However, all of these figures shown in Table 5 are the relatively low cost areas compared to other parts of the United States. The Iowa yields are also higher due to the high land charges that are incurred in that state.

The land charges are somewhat difficult to estimate, but they are generally based on either a cash rental value for the land or taking the product of the land per acre times an interest rate. For example, if the land would be valued at $1,500 per acre and the interest rate on a Federal Land Bank loan is 8%, why, the estimated land charge per acre would be $120. Of course, when the farmer already owns his land, he might not actually charge himself for this, but it is over the long run that a cost has to be considered. Table __ shows the estimated corn grain production costs. And again I want to emphasize these numbers are based on averages for each region, they are not necessarily indicative of what individual growers may achieve, which may be higher or lower, of course, than these.

Table 6 shows the estimated net cost of corn for production of ethyl alcohol. Total alcohol production costs for corn grain can be reduced by taking credit for the still large byproducts of the fermentation process. The credit for distiller's dried grains which are used as an ingredient in cattle feeds amounts to approximately $38 per ton of corn used, based on price levels of approximately 1 year ago. We use that price because the other costs associated with our operating facility were based on approximately that time period. Therefore, the net cost of each ton of corn for alcohol after deducting the stillage credit is between $43 and $65 per ton, depending on the region.

Using corn residues as an energy for chemical feedstocks, was our third alternative for fuels from biomass. Specifically we examined the use of residues to produce either substitute natural gas or ammonia. And residues for this study are defined as the aerial portion of the corn plant exclusive of the grain. We did not consider the roots in our analysis as far as the residues are concerned.

TABLE 5

MAJOR COMPONENTS OF ESTIMATED CORN GRAIN PRODUCTION COSTS, BY SELECTED REGION, 1976

	East Central Illinois	Central Iowa	South Central Nebraska	Texas High Plains
Total Acres (000)	4,900	6,400	1,200	100
Yield Per Acre (Bushels)	122	100	117	140
Yield Per Acre (Tons)	3.42	2.80	3.28	3.92
	-Dollars Per Acre-			
Preharvest Variable Costs	97	88	96	155
Harvest and Hauling Variable Costs	16	19	24	59
Machinery Ownership Costs	29	30	53	51
Land Charge	145	134	78	80
Management Charge	21	18	20	25
Total ($/Acre)	308	289	271	370
Total ($/Ton)	90	103	83	94

TABLE 6

ESTIMATED NET COST OF CORN FOR
PRODUCTION OF ETHYL ALCOHOL, BY REGION
($/Ton)

Area	Corn Production Cost	Credit for Stillage[a]	Net Cost of Corn
East Central Illinois	90	38	52
Central Iowa	103	38	65
South Central Nebraska	83	38	45
Texas High Plains	94	38	56

(a) Based on 19.8 pounds stillage per bushel of corn and value of distillers/dried grains = $105 per ton (as of January, 1976).

Under current production conditions, residues are either left on the soil to decay or else they are collected or grazed as feed for livestock. At any rate, the total cost of residues must include a compensation to farmers for the residue value either as a feed source or as a soil maintenance material in addition to the residue collection and transportation costs.

There is probably not a constant relationship between the amount of grain produced and associated residues. Certainly this ratio is subject to climatic factors, rate of growth, the variety of corn and also the location of production. Our analysis shown in Table 7 of the quantity and composition of corn residues is based on some data developed by Dr. Richard Vetter of Iowa State University which he reported in 1973. His research was conducted over a 4-year period in the corn belt and he took measurements at a 23% kernel moisture content, which is fairly typical of grain moisture contents at harvest time in the midwest. At this moisture content Vetter found that the grain comprised 53.1% and the aerial residues 46.9% of the total dry weight of the corn plant. Now, if the grain was harvested earlier in the season at a 28% moisture content, the ratio changes to about 49.1% grain or roughly 51% residue on a dry weight basis.

Table 8 shows the amount of grain and residues produced under various yields. Residue production on a dry weight basis ranges from roughly 3,000 lb or 70 bushels per acre up to about 6,300 lb or 150 bushels per acre. Our average corn belt yield projections of 160 bushels per acre, if you consider these to be realistic, would mean that about 3.4 tons of dry residues could be produced on each acre by the year 2000. And again, Table 8 assumes a constant ratio of grains to residues at varying yields. However, this does need to be verified experimentally.

Now, the same four geographic regions that were used in the analysis of corn grain are used in the estimates regarding residue production. The estimated density of dry residue production as seen in Table 9 ranges from 36 tons per square mile in the Texas high plains area, to 785 tons per square mile in central Illinois. Iowa is close behind Illinois with a density of around 670 tons per square mile.

If you use a rough Illinois and Iowa average of 730 tons of dry residue produced per square mile, a 50-mile radius surrounding a substitute natural gas or ammonia facility would supply over 10 times the annual raw material requirements of a single plant (see Table 10). Within a hundred mile radius in this particular region total dry residue production is estimated around 23 million tons or over 40 times the annual plant requirement. So it seems evident, therefore, that the raw material requirements for a processing facility could certainly be met in the intensive corn producing areas of the corn belt and without taking all of the residues or the total hypothetical supply.

TABLE 7

DRY MATTER IN THE CORN PLANT
AT TWO KERNEL MOISTURE CONTENTS

Plant Component	Percentage and Volume in 2000 Lbs Dry Matter					
	Kernel Moisture 23%			Kernel Moisture 28%		
		%	Lbs		%	Lbs
Grain (Kernel)		53.1	1062		49.1	982
Cob	46.9	10.0	200	50.9	9.7	194
Stalk		25.3	506		25.1	502
Leaf		5.5	110		10.5	210
Husk		6.1	112		5.6	112
Total Dry Matter		100.0 Percent	2000 Pounds		100.0 Percent	2000 Pounds

TABLE 8

QUANTITY OF RESIDUES UNDER DIFFERENT CORN YIELDS
AT "NORMAL" HARVEST PERIODS

Grain Yield at 84.5% Dry Matter, bu/acre[a]	Equivalent Grain Yield At 77% Dry Matter, bu/acre[b]	Lbs. Grain/Acre		Lbs. Residue/Acre	
		Field Wt.	Dry Wt.	Field Wt.	Dry Wt.
70	77	4312	3320	6,867	2939
100	110	6160	4743	9,811	4197
150	165	9240	7115	14,717	6299

(a) For statistical reporting purposes, yields are reported at 15.5% moisture content.

(b) "Normal" moisture content at harvest assumed to be 23%.

TABLE 9

ESTIMATED DENSITY OF RESIDUE PRODUCTION
1976
(Tons Per Sq. Mile)

	Production Density	
	Field Wt.	Dry Wt.
East Central Illinois	1833	785
Central Iowa	1570	672
South Central Nebraska (irrig.)	584	250
Texas High Plains (irrig.)	85	36

TABLE 10

ESTIMATED PRODUCTION OF RESIDUES
WITHIN SPECIFIED RADII

ILLINOIS AND IOWA
(DENSITY = 730 DRY TONS/SQ. MILE)

Distance From Processing Plant, miles	Cumulative Total Production 1000 Tons	Percent of Total Cumulative Production Necessary to Supply 551,000 Tons/Year
0-10	229	100+
0-50	5,735	10
0-100	22,944	2

Table 11 indicates three collection alternatives that might be used to assemble corn residues. This topic, of course, will be addressed in considerably more detail this afternoon by the gentleman who is speaking from The Hesston Corporation, and I am sure he might touch on some other alternatives that we have not considered here. But what we have listed here, and this is based on some data reported back in last July from Stanford Research Institute on their residue study, we have the large round bale here which might weigh anywhere from 1,000 to 2,500 lb and with a density of about 10 to 13 lb per cu ft.

A second alternative would be the large stacks of residue which look somewhat, at least to me, like a large loaf of bread as you see them sitting out in the field and this again could be produced by currently available machinery. This produces a stack ranging anywhere from 3 to 10 tons in total weight with a density of about 4 to 6 lb per cu ft.

The third alternative is field cubing of residues which produces small cubes of approximately an inch to an inch and a quarter with the highest density of around 16 to 22 lb per cu ft.

And then, of course, another alternative which we have not considered in any detail would be baling residues in, of course, bales comparable to those produced which you see on many farms now to bale hay. The weight of these, I would estimate, might be anywhere from 50 to 100 lb.

Bulk density and hauling distances are important variables when considering the use of residues as an energy feedstock. Semi-tractor trailers are limited, I think, in many states to a maximum load of around 23 to 24 tons, and if you take what I think might be a typical sized trailer, this might hold approximately 3,500 cu ft of volume. And if you just consider a single truckload of them with, say, chopped residues at a density of, say, 6 lb per cu ft, you might not even reach half of the load limit on a weight basis before you would run out of volume on a physical basis or physical space, rather. Therefore, it is obvious that some economic balance has to be drawn between savings in transportation costs which would be due to residue densification and the costs of this densification process.

If you assume that 24 tons are hauled per trip, and we are assuming here that the residue dry matter is about 43%, and that 60% of the plants' volume is supplied within a radius of 20 miles, you get another 30% between 20 and 50 miles and then 10% between 50 and 80 miles, the total cost of transporting roughtly 1.3 millions of field weight residue to a processing facility is about $2.3 million. For a clearer picture of this cost estimate see Table 12. This would be equivalent to an average cost of about $1.77 per ton of field weight, or converted to a dry weight basis the cost would be about $4.13 per ton. Again this assumes an even distribution of the residues supplied throughout the region.

TABLE 11

RESIDUE COLLECTION ALTERNATIVES

Package Type	Package Weight	Package Density, lb/cu ft
1. Large round bale	1000-1500 lbs 2000-2500 lbs	10-11 13
2. Air-packed rectangular stack (chopped)	6-20,000 lbs	4-6
3. Field cubing	1-1/4-inch cubes	16-22

Source: Stanford Research Institute, An Evaluation of the Use of Agricultural Residues as an Energy Feedstock, Vol I (July, 1976).

TABLE 12

ESTIMATED
RESIDUE TRANSPORTATION COSTS TO SUPPLY
1,288,000 TONS (FIELD WEIGHT) PER YEAR

AVERAGE HAULING RADIUS = 27 MILES
TONS HAULED PER TRIP = 24 TONS

	Hauling Radius in Miles			Average or Total
	0-19.9	20-49.9	50-80	
Percent of Total Manufacturing Plant Volume Supplied	60%	30%	10%	100%
Total Cost	$935,514	$904,508	$436,730	$2,276,752
Total Cost Per Ton, Field Wt.	$1.21	$2.34	$3.39	$1.77
Total Cost Per Ton, Dry Wt.	$2.83	$5.48	$7.91	$4.13

Note: 1,288,000 tons at 42.8 percent dry matter = 551,000 tons dry matter.

Note: 60%, 30%, and 10% figures based on Baumel's 1976 Iowa State study of corn grain terminal delivery distances during autumn.

Now, if--and I think this is a big if--the residues can be air dried or sun cured, in the field to approximately an 80% dry matter rather than the 43% which we previously assumed, the transportation costs per dry ton fall by about half to roughly $2.25. These cost estimates are shown in Table 13. However, I think there are a lot of questions about feasibility of air drying or sun drying. Because the dried material is less dense than freshly harvested, there is, I think, greater need for some type of densification such as baling or field chopping. It would seem to me the feasibility of sun drying these residues during the winter months in the corn belt is debatable. Also, the moisture content of the residues presumably would be highly dependent upon weather conditions at the particular time when they were gathered, including the rainfall and wind and temperature and snowfall.

I feel that the questions (1) what is the real residue moisture content when they are collected and (2) what is the degree of variability in this moisture content and (3) what are the relationships between moisture levels and densification requirements are topics that need to be examined in future research experiments.

Now, the transportation costs are just one aspect of the total delivered costs of corn residues to processing plants. The cost of collection and assembly of the residues on a farm must also be considered along with the cash payment to the farmer for the value of the residues. The total cost of delivering residues containing 43% dry matter ranges between $25 and $70 per dry ton depending on the collection alternative as shown in Table 14. The collection costs are here again based on the SRI data. I put together my own estimates on what you might have to pay the farmer. The delivered costs of residues on an 80% dry matter falls to between $16 and $45 per ton of dry weight.

The cash payment to the farmer is based on comparable fertilizer and feed costs, and this cash payment I have estimated to range between $5 and $15 per ton of dry residue depending on whatever alternative might be available to him. If the farmer is a cattle feeder and he wishes to use residues as a forage substitute and if hay is worth around $60 a ton, which I think a cash payment of at least $15 per ton on a dry weight basis to the farmer would be necessary. If the residues otherwise would be left on the ground, this cash payment might be substantially lower, around $5 a ton.

Residues contain about 5-1/2% ash, which has no value, at least from an energy standpoint, and, therefore, after eliminating the ash content the delivered cost of residues is increased slightly. On a cost per pound basis values ranged from about 1.3 to 3.7¢ at 43% dry matter, and at 80% dry matter the cost estimates ranged from about 0.9 to 2.4¢ per lb. The cost per pound data is given in Table 15. Additional research, as

TABLE 13

ESTIMATED
SUN-CURED RESIDUE TRANSPORTATION COSTS TO SUPPLY
689,000 TONS (FIELD WEIGHT) PER YEAR

AVERAGE HAULING DISTANCE = 27 MILES
TONS HAULED PER TRIP = 24 TONS

	Hauling Radius in Miles			Average or Total
	0-19.9	20-49.9	50-80	
Percent of Total Manufacturing Plant Volume Supplied	60%	30%	10%	100%
Total Cost	$499,853	$485,070	$233,600	$1,218,523
Total Cost Per Ton, Field Wt.	$1.21	$2.34	$3.39	$1.77
Total Cost Per Ton, Dry Wt.	$1.51	$2.93	$4.24	$2.21

Note: 689,000 tons at 80% dry matter = 551,000 tons dry matter.

TABLE 14

ESTIMATED
DELIVERED COSTS OF CORN RESIDUE
UNDER
THREE COLLECTION ALTERNATIVES

$/TON FIELD WEIGHT
AT 43% DRY MATTER

	Large Round Bale	Chopped and Rectangular Stacked (Air Packed)	Field Cubing
Total Cost Per Ton Field Weight (including cash rental, residue collection, and transport)	10.55-27.00	11.90-24.80	11.90-29.80
Cost Per Ton Dry Weight:			
At 43% Dry Matter	24.55-62.80	27.65-57.65	27.65-69.30
At 80% Dry Matter (sun dried)	15.50-40.95	17.20-38.20	17.20-44.45

TABLE 15

ESTIMATED DELIVERED COSTS
OF COMBUSTIBLE ORGANIC MATERIAL
OR FERMENTABLE SOLIDS
IN CORN RESIDUES

(Cents Per Pound)

Collection Method	Dry Matter Content at Time of Collection 43%	80%
Large Round Bales	1.3-3.3	0.9-2.2
Chopped and Stacked	1.5-3.1	0.9-2.0
Field Cubed	1.5-3.7	0.9-2.4

Note: Ash Content = 5.5%; therefore, there are 1890 pounds combustible organic matter or fermentable solids in each 2000 pounds of dry residue.

I previously indicated, is needed to verify the costs and practicality of collecting and transporting these residues. There are problems which we did not even consider, such as the potential logistical problem that might be associated with delivering a million tons of residues to a processing plant over a 4 to 6 months period, particularly during the winter months that you experience in the corn belt.

We move on to the final topic: the energy balance in corn agriculture. Various authors have estimated the ratio of energy produced per energy consumed in growing and harvesting corn grain. Each has looked at the problem in a little bit different way and naturally we have got some variability in these energy balance ratios. These different ratios are shown in Table 16. Pimentel's ratio of energy produced or energy consumed was the lowest of price sources that we looked at, around 2.5, and Dr. Aldrich of Illinois showed a ratio of about 5.7, and if you average all these together you come up with a gross type of estimate of around a ratio 3.7 of energy output-input.

Now, we decided to use some data recently developed by the U.S. Department of Agriculture on energy consumption in grain production. This data is given in Table 17. Now, one reason we used this is that the USDA data differentiates energy utilization for various crops by state, therby accounting for differences in cultural practices. And lower heating values were used for both production inputs and outputs. It should be noted that the 1974 yields in the corn belt were adversely affected by drouth and, therefore, the ratios shown are probably on the conservative side. Perhaps in a more normal crop year they might go up by 10 to 15%.

Energy used per acre in producing corn grain, Table 18, ranges from about 6.8 million Btu's in Iowa up to about 14 million Btu's in Texas. Average energy balance for corn grain is 3.1, which is roughly comparable to the 3.7 which I mentioned earlier compiled from other sources. Iowa and Illinois energy balance ratios for the production of grain plus residues, Table 19, is approximately 2.7 to 2.8, and the lower ratio presumes that the residues would not be sun dried in the field and, therefore, considerable energy would have to be expended in mechanically drying the residues to levels which would allow safe storage. And I base this on what might be comparable to having to dry corn grain. This may not be a good analogy.

If no mechanical drying of residues was necessary, the energy balance for grain plus residues, Table 20 rises to between 5.2 and 5.5 for Illinois and Iowa with lower ratios in Nebraska and Texas.

TABLE 16

ENERGY IN CORN GRAIN AND
RATIO OF ENERGY PRODUCED
PER ENERGY CONSUMED

Source	Assumed BTU/LB Corn Grain	Ratio Energy Produced/Energy Consumed-Corn Grain
Pimentel	6,336	2.52
Cervinka, et al	6,624	3.25
Aldrich, et al	6,947	5.70
Scheller, et al	6,103	2.86
Heichel	8,913	4.30
Average	6,985	3.73

TABLE 17

NET ENERGY PRODUCTION
FROM
CORN SILAGE

(Based on 1974 Silage Yields)

State	Silage Yield Field Weight, tons	Energy Used Per Acre in Silage Production, 1000 BTU's	Ratio of Energy Contained To Energy Used x:1
Wisconsin	9.4	5,907	5.1
Indiana	11.5	7,622	4.9
Texas	13.0	19,517	2.1
California	18.5	15,223	3.9
United States	10.4	7,183	4.7

Note: Assumed 3,218,000 BTU's/ton silage containing 65.6% H_2O (lower heating value).

Based on Firm Enterprise Data System statistics.

TABLE 18

1974
NET ENERGY PRODUCTION
FROM
CORN GRAIN

State	Grain Yield Per Acre, tons	Energy Used in Grain Production 1000 BTU's	Ratio of Energy Contained To Energy Used x:1
Illinois	2.32	7,734	3.5
Iowa	2.24	6,806	3.9
Nebraska	1.90	11,933	1.9
Texas	2.58	13,999	2.2
United States	2.00	7,604	3.1

Note: Assumes 11,764,000 BTU's/ton of corn containing 15.5% moisture (lower heating value).

TABLE 19

1974
NET ENERGY PRODUCTION
FROM
GRAIN PLUS RESIDUES

(Residues Not Sun-Dried)

State	Grain & Residue Yield Per Acre, Field Weight	Energy Used in Grain & Residue Production/Acre 1000 BTU	Ratio of Energy Contained to Energy Used x:1
Illinois	6.40	17,450	2.7
Iowa	6.16	16,279	2.8
Nebraska	5.24	20,899	1.8
Texas	7.09	26,026	2.0

Note: Assumes 4,784,000 BTU's/ton of residues containing 57.2% moisture and 11,764,000 BTU/ton of grain containing 15.5% moisture.

TABLE 20

1974
NET ENERGY PRODUCTION
FROM
GRAIN PLUS RESIDUES
(Residues Sun-Dried)

State	Grain and Residues Per Acre, Field Weight	Energy Used in Grain & Residue Production/Acre 1000 BTU	Ratio of Energy Contained to Energy Used x:1
Illinois	4.50	9,623	5.2
Iowa	4.34	8,740	5.5
Nebraska	3.69	14,358	2.8
Texas	4.99	16,971	3.3

Note: Assumes 10,360,000 BTU's/ton of residues containing 20% moisture and 11,764,000 BTU/ton containing 15.5% moisture.

Table 21 summarizes some of the main points that I have been hitting on. Looking at the total United Staes, we produce about 40 million tons per year on a dry weight basis of silage, about 131 million tons of grain and 116 million tons of corn plant residues. In the most intensive corn producing areas the density of grain production is approximately 750 to 800 tons per square mile and accompanied by roughly 700 dry tons of residues per square mile. Estimated costs of corn as an energy feedstock ranged from about 2.4 to 3.0¢ per lb for dry material for silage, from about 2.3 to 3.3¢ a lb for dry grain, assuming a stillage credit there, and a residue cost somewhere in the neighborhood of 1 to 2¢ per lb.

As indicated previously, I think the costs of residues needs to be the subject of some additional verification since there is very little published data available on this. Also the dry matter content of residues needs some additional work.

The ratio of energy consumed in corn biomass production ranges from about 2.7 to slightly over 5.0, depending on which plant component is utilized. Again there may be considerable latitude in these ratios depending upon the exceptions made by the various researchers. It will naturally be lower once the energy costs of converting the biomass into some type of fuel or chemical are considered.

Question: I have an observation, not a question. The ratios of energy contained to energy should be borne in mind in terms of the efficiency of recovering the contained energy. So if you come up with a number like 2 for 1, you are essentially running at a loss because there are very few things that will recover 50%. And some of the things we are going to be talking about, like ethanol and furfural, you are going to need a ratio of 4 to 1 just to begin to think about it.

TABLE 21

SUMMARY--CORN BIOMASS

Total U.S. Production		Million Dry Tons
Silage	10.3 million acres	40
Grain	68.0 million acres	131
Residues		116
Density of Production (Corn Belt)		**Dry Tons/Sq Mi**
Silage		80
Grain		750-800
Residues		700+
Estimated Costs/Lb Raw Material		**¢/Lb**
Silage		2.4-3.0
Grain (with stillage credit)		2.3-3.3
Residues @ 43.0% D.M.		1.3-3.2
@ 80.0% D.M.		0.8-2.1
Energy Output/Input (Corn Belt)		
Silage		5.0
Grain		3.5-4.0
Grain + residues:		
Residues @ 43% D.M.		2.7
Residues @ 80% D.M.		5.0-5.5

ETHANOL AND FURFURAL FROM CORN

Dr. W. J. Sheppard

Battelle Columbus Laboratories

I am going to talk about making furfural and alcohol from corn and compare these results with some that we got in calculating the costs of making furfural and alcohol from bagasse. I will also compare the costs that we derive for making furfural and alcohol with some of the current commercial prices for these commodities.

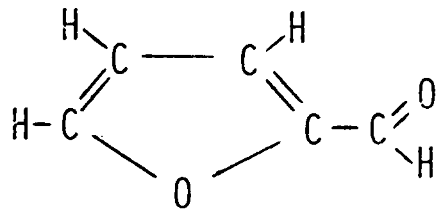
One of the problems that you run into when you talk about furfural is explaining what furfural is. Figure 1 shows the configuration of the furfural molecule. It's a five-membered ring, but because of the double bonds and the unshared pairs of electrons on the oxygen it has some aromatic character to it, which means that it is sort of like benzene. It also has a nice odor, a sweet fruity odor not too different from benzaldehyde, which is superficially resembles. The market for this is about 150 million pound, which is not large and it's not small as chemicals go. It sells for around 50¢ a pound right now. It is in short supply and people are on allocation and Quaker Oats is selling all that they can produce and they are building a new plant to produce even more.

What's furfural used for? Well, it can be used as a solvent and it can be used to extract the aromatic materials in a lubricating oil stock to upgrade the quality of the lubricating oil. It can be mixed with petroleum fractions and then the fraction distilled and you can recover the butadiene or the isoprene in this way. We call that extractive distillation. It can be used for making resins. It can also be converted to a number of other things. We can make the aldehyde into an alcohol group and then we can make foundry core binder resins. If you are making a casing, the cheapest way to machine a hole in the casing is to put a rod of sand bound with a resin in before your pour the metal. So this is what is done and these are called a core and we use a binder resin. It turns out that furfural alcohol makes the best resin. Unfortunately, at about 50¢ a pound the phenolic resins at half that price are beginning to compete quite actively.

We can also make other things that have names like tetrahydrofuran, which is furfural minus the aldehyde group shown on the right in Figure 1 and with four extra hydrogens attached.

Now, we are interested in furfural because it represents a chemical that can be made and one that is in short supply now. We can see that there is a fair market. We could double or triple the amount and sell it. We could get some money. We could also replace phenol and other materials that are aromatic chemicals which come from the petroleum company. So thus we would displace some fuel.

FURFURAL



CURRENT MARKET: 150 MILLION POUNDS

PRICE: APPROXIMATELY $0.50 PER POUND

USES: SOLVENTS, RESINS, CHEMICAL INTERMEDIATE

Figure 1

There is an interesting story behind furfural. In about 1920 a man named Harold Brownley at Miner Labs in Chicago was trying to take oat hulls to use for animal feed because there was a shortage of molasses. He tried in his lab to digest the oat hulls with sodium hydroxide, and that did not improve it. Then he tried digesting them with acid, and that did not improve it, and suddenly they discovered in the feeding trials that oat hulls were not so bad just as they were. But he had done 2 years of work and he wanted to write it up. So they completed his work for publication and they noticed there was an energy balance or a material balance problem. They were 20% short. So they tried to find out what happened to that 20% that disappeared. When they looked they found that much of what had distilled out by accident in the digestion with acid was furfural. So they went to the biggest manufacturer or biggest maker of oat hulls, which was Quaker Oats, and they went into business with Quaker Oats. Originally furfural was two and a half dollars a pound, but by aggresively lowering the price they got furfural down in just a few years to about 17-1/2¢ a pound. These big markets developed and now the price is creeping back up with the general inflation. However, I thin 17-1/2¢ in 1926 was a higher price than 50¢ today.

Now, there are other compounds that we could make from the corn residues because the furfural starts out as a five carbon sugar. In fact, it starts out as a five carbon sugar in a long chain that we will call pentosan. We can hydrolyze the corn cob material or corn stover material to the five carbon sugar, and we could isolate it and sell it as xylose, but there is not much of a market. We could take the xylose and we could hydrogenage it and sell it as xylatol and this is a sweetener that is low in calorie value. Xylatol is supposed to be noncarcinogenic, in other words, it does not rot your teeth out, and if you do not mind the laxative problem from the xylatol then it may be a great thing. In fact, in Finland they have claimed that it actually heals the cavities in teeth. However, the market volume for xylatol is likely to be small, so we ignored it.

The C_6 sugars, the cellulose, can be hydrolyzed to glucose. Then you can do things with the glucose. It is possible to make hydroxymethyl furfural. Merck tried selling hydroxylmethyl furfural and it turns out it is about as useful as last year's bicentennial neckties are now. They were not able to get anybody interested in it, even though it was a nice interesting compound. Likewise you can make the hydroxymethyl furufural into lebulinic acid that has a very small specialty market, but we ignored it.

One of the decision factors for ignoring these uses was the graph in Figure 2. To make this graph we took about 150 organic chemicals and plotted the price versus the volume on a log plot. The range we are working with is from about 10 billion pounds plotted against thousands of dollars per pound.

From the graph it can be seen that the things that are physiologically active such as the dyes which are interacting with your eyeballs and the medicinal chemicals flavorants, and ordorants, have a rather high price and a low volume. The things that are basic building blocks have a large volume and a low price.

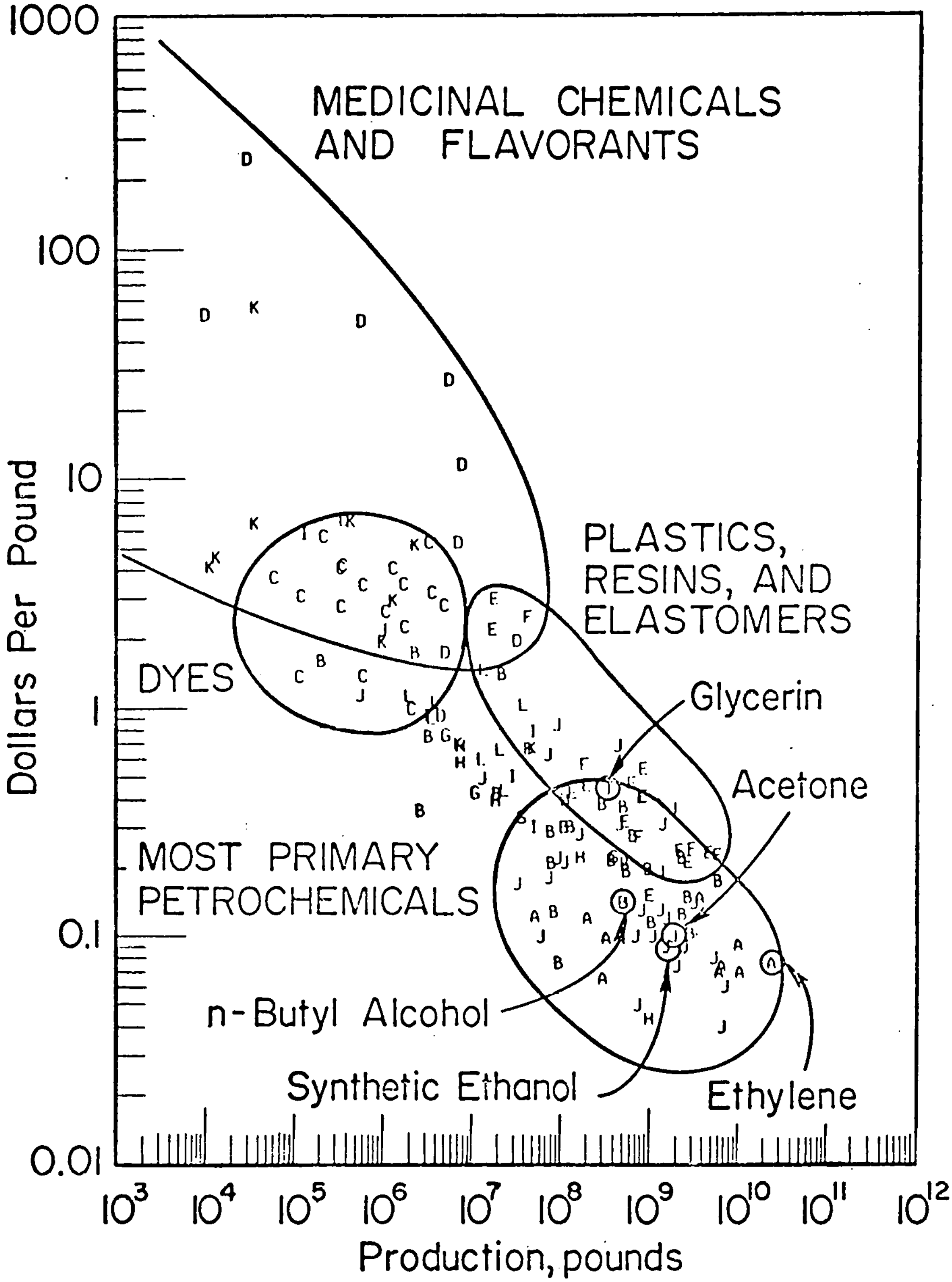


FIGURE 2. PRICE VERSUS VOLUME, ORGANIC CHEMICALS BY TYPE, 1974

And furfural at 50¢ a pound, if it is 50¢ a pound, falls into the large volume and low price area of the graph. Now, what we are saying is that we are going to bave to get the price down if we want to get the sales volume up. So this is the reason that we try to look at the biggest possible market.

I mentioned that we make the furfural from the five carbon sugars. The five carbon sugars are found in almost all agricultural products. Corn cobs and oat hulls are especially rich in these sugars. Bagasse has a little bit less. In Finland they are making furfural from birchwood scrap. Table ___ shows how much furfural can be produced from various crops. The numbers in parenthesis are some Battelle estimates. The numbers that are not in parenthesis come from Dunlop and Peters' book on the furans. Furfural also can be made from olive pits or date seeds or even from pinewood waste, although the pinewoods and the soft woods in general have about half the content of the things such as birchwood and other hardwoods.

So with corn cobs we have 30% pentosans. By the time we run the reaction we get about 13 pounds of furfural out.

Now, let me just tell a little bit of the history of furfural production. Quaker Oats, as I mentioned, started out with oat hulls, but if you are selling oat hulls for animal feed and selling oat hulls to your furfural plant, you are competing with yourself and you run up the price of the oat hulls even if it is the transfer price. So there is only a limited amount of oak hulls available and some of that is dedicted to animal feed.

So the n Quaker Oats looked at using corn cobs to produce furfural. During World War II, when it was necessary to get lots of butadiene out of petroleum fractions for use in the synthetic rubber program, a plant was built in Memphis, Tennessee, to use cotton seed hulls. But it was soon found that cotton seed hulls were more useful or had a higher price for an animal feed than they did as a raw material for furfural, so this almost disappeared as a raw material and people brought corn cobs down the Illinois River by the bargeload all the way down to Memphis.

Down in Belle Glade, Florida, and at LaRomana in the Dominican Republic bagasse is used to produce furfural as it is elsewhere in the world. And as I mentioned, in Finland they use the birchwood.

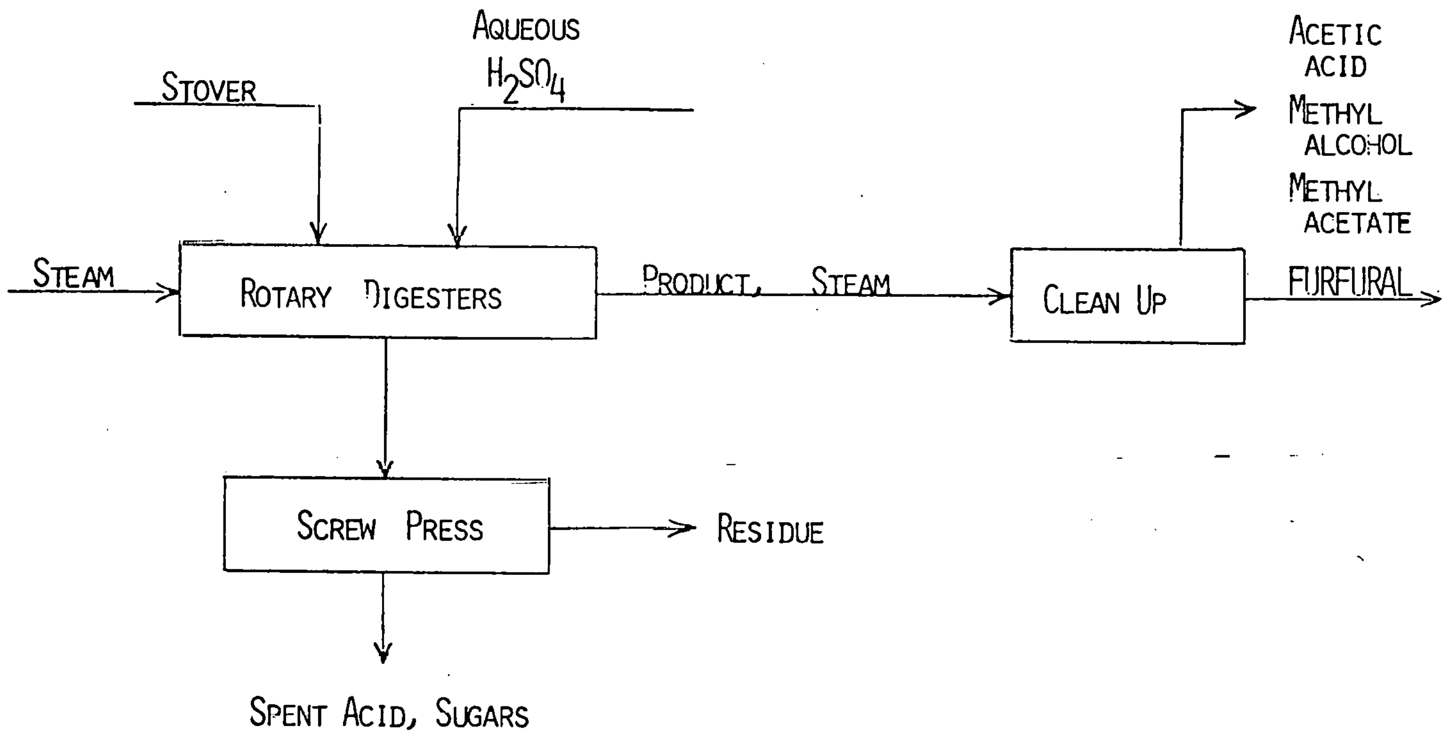
Now we are looking at using the corn stover to make furfural and as a first approximation it yields about like that of bagasse, but we think we can get a little higher yield.

A process for making furfural is shown in Figure 3. This figure shows the process using a rotary digester. This is the old-fashioned tried and true approach. Some people have used continuous digesters. At the beginning of the process we add our stover and some sulphuric acid and we run in high pressure steam. We have to use 28 tons of steam for every ton of furfural that we get out. It distills over with the steam. Then we clean up the products and we estimate a furfural yield of about 8-1/2% of the

TABLE 1

MADE FROM FIVE-CARBON SUGARS

	Pounds of Furfural Per 100 Pounds of Raw Material
Corn cobs	13
Oat hulls	12
Bagasse	(8) 9
Birchwood scrap	(7)
Rice hulls	6.3
Corn stover	(8.5)



FURFURAL PROCESS

Figure 3

stover we started with. In addition the acetic acid yield is as much as 5-1/5% of the original amount of stover. We think that it is important to recover the acetic acid and use it. In addition there are 1-1/2% of methyl alcohol. Another product is methyl acetate. Its in the literature as acetone but I suspect that it is methyl acetate and I have reported it that way. They both boil at the same place and I do not really believe that acetone is produced.

Now, after we have done this digesting and if we use the rotary digester it will take 6 or 8 hr, we then take the material and run it through a screw press. From the screw press we get out a residue that is 35% water and we have some spent acid, and there is a little bit of hydrolysis of the cellulose to give us glucose. We can run the glucose over to an alcohol plant if we have one.

Now, we analyzed the cost of this process. First let me tell you what some of the ground rules are for the cost analysis. We used $36 a ton for the raw material on a dry basis. Now, you remember Dr. McClure's numbers ranged from $27 up to as much as $70. And we figured that $36 was a pretty good number for a reasonable hauling distance. We then calculated the sensitivity to this cost. Our operating costs include labor and supervision and maintenance and just about everything else we could thing of. Maintenance is as great a cost as labor in this kind of an activity.

Our annualized cost was made on the basis of taking plant and offsites, and the offsites are almost equal to the cost of the plant in many cases. Working capital, accounts receivable, inventory, and startup costs were all considered in the cost analysis.

We calculated cost using 60% debt and 8-3/4% interest on that debt and a 14% return on equity after taxes. We think these assumptions represent a fair picture of the kind of economics that one might use. Then we calculated what would be the annualized payments. These payments would pay off the interest and the equity and would provide for replacement of the capital.

Then we calculated the value of the residues. We used a dollar a million Btu lower heating value for the byproducts. The acetic acid sells on the market for 17¢ a lb, but we are getting the acid out diluted with a lot of water and a lot of cleanup, so we just valued it at 6¢ a lb.

I might mention about this lower heating value. People who report heating values generally report a higher heating value, which is what you get in a bomb colorimeter. However, in the bomb colorimeter any steam that is formed gets condensed again and you get that heat back. But the lower heating value is what you get when you burn the substance and let the steam go up the stack. So the steam is not condensed and you do not get the heat back from the condensation process. This means if you have a moist material than you not only are diluting the calorie value with the water, but extra energy is needed to evaporate the water. And likewise if there is hydrogen in the compound, that hydrogen forms water which also is lost as steam. This is why we have used lower heating values. For fossil fuels using lower heating values makes a difference of maybe 5 or 6%, but for biomass materials and municipal solid wastes and things of that sort it can be as much of a difference as 25%. So we want to keep in mind what heating values we are dealing with.

The way we calculated our costs was to go to the literature. We found a book on sugarcane byproducts written by Paterau. He had estimated what it would cost to build a small plant using bagasse. We scaled it up using a scale factor of 0.65, which means we put it on a log plot and used the slope of 0.65. This is a common way that engineers multiply their ignorance. They take one number and then they draw a straight line using an assumed scale factor of 0.65 or 0.6 or 0.7. A scale factor of 0.6, just to set the stage, means if you build the plant twice as big it only costs you 1.6 times as much. Or if you build it five times as big it only costs three times as much. So that is the kind of scale factor we are talking about.

We assumed our electricity would cost 3¢ a kw-hr and our high pressure steam would cost 3¢ a thousand lb of steam. We had low pressure steam coming out and we gave ourselves a credit of $2 a thousand lb for that.

The results of this analysis are shown in Table 2. These estimates were made for a plant that would use about 1,600 tons a day of stover, a little over half a million tons per year if we operate the plant 330 days. It is comparable to the size unit that Dr. McClure was talking about, 550 thousands of tons per year. And we are producing 135 tons a day of furfural, which is 45,000 tons a year or if you like big numbers 90 million lb per year. The total U.S. production of furfural is 150 million lb per year, so we are talking about a large plant.

Now, the large plant has an advantage in that it is cheaper because of the scale factor. However, it runs up our costs of collection, because as you go to ever-increasing circles you increase your average cost of material. That is different from many processes where you expect the costs of your raw material to stay constant or even decrease as you increase the scale.

Now, our battery limits plant, that means the equipment in place, we calculated as costing about 50 million dollars, but by the time you put in the offsites and the fire station and the little lab and the cafeteria and some parking lots and storage and so on, it gets up to 80 million dollars. This is another thing to watch, to make sure that you are looking at the whole plant and not just the battery limits plant when you see numbers.

As you can see from Table 2 the byproduct credits are an appreciable factor here. The byproduct credits are based on both the acetic acid and on the heating value of the residues and on the recovered steam, but it does not include anything for the sugars that might be in the spent solution and for the methanol or methyl acetate.

Notice that the cost of furfural from our stover comes to 39¢ a pound at the plant and usually you use a rule of thumb that says 30% extra for your costs of marketing and distribution and that brings the cost up to 50¢ a pound, which is about what Quaker Oats is charging now. So this gives us a little bit of confidence in our numbers.

TABLE 2

COSTS OF FURFURAL FROM CORN STOVER

	Millions of 1976 Dollars
Raw Material	19.008
Operating Costs	16.248
Annualized Capital Charges	9.225
By-Product Credits	(9.555)
TOTAL	34.930
Cost Per Pound	$0.39
Cost With Distribution at 30%	$0.50

Now, how does the cost of furfural vary with the raw material costs? Figure 4 graphically illustrates the answer to this question. We valued the raw material at $36 a ton but if you have zero costs for your material, the furfural will cost 17¢ a pound, and if the raw material costs $20 a ton the furfural will cost around 28¢. Now what it means is that if we are going to make money on furfural alone, even with all these byproduct credits, then we have got to cut down the costs of the material. But you will see later that we play some games where we take the residue and instead of burning it we get some other values out of it and that makes our cost estimate look a little better.

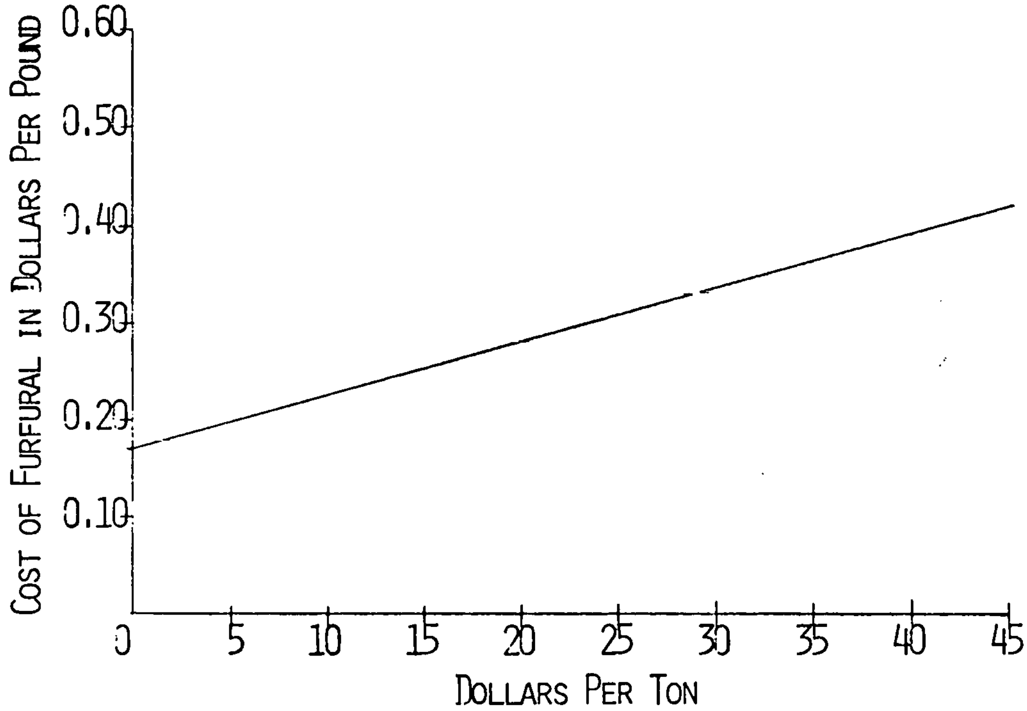
We also compared the cost of making furfural from corn stover with the cost of making it from bagasse. This comparison is shown in Table 3. With bagasse you are ahead as far as the cost of collection because you have to bring the bagasse to the sugar mill with the sugar juice, so that the costs of collection are borne jointly by the sugar venture and by the bagassee venture. And when we did our study of sugar we found that $1 a million Btu for bagasse lower heating value was a reasonable number. That is about what low sulphur coat sells for in small amounts delivered. It also gave us a cost of ¢6 a pound for the fermentable sugars. That also is a reasonable number, so that we think this is the best combination to use. And you see from the table that the operating costs are the same for bagasse and corn stover.

The capital charge is higher in the case of stover. This is because we have a larger working capital with corn stover. The product is more expensive and we have to store several months' supply and that runs up the capital investment. We also have to store some raw material and that runs up the capital investment.

The byproduct credit is a little higher for the bagasse for the same size plant because bagasse has more lignin than stover and so we gave ourselves a higher credit per pound because there were more Btu's per pound.

So here with the bagasse our costs are 29¢ without distribution and 38¢ with, and what this means is that you are better off going with bagasse than with corn stover. This is due principally to the cost of the raw material.

I would like to mention just one other thing about the history of furfural that illustrates something having to do with the whole biomass problem and that is duPont was using furfural to make nylon. They developed a way of making nylon using butadiene. Butadiene started to be very cheap. Of course, they distilled it out using the furfural, but nobody talks about that. The butadiene was cheap and so they said to Quaker Oats, "go find some other customer." So Quaker Oats worked real hard and found some other customers. Then duPont wanted to make lycra spandex material, urethane, and they wanted to use tetrahydrofuran, so they went back to Quaker Oats and said, "Hey, we would like to buy some furfural," and Quaker Oats said, "We would have to build a new plant for you and we do not want to get tied up with you because we know you will walk away." Well, what happened was that they picked the largest output sugar mill in the world, LaRomana in the Dominican Republic Centrala Romana. They built a furfural plant using bagasse and it was operated by the South Puerto Rico Sugar Company using technology transferred or licensed from Quaker Oats.



FURFURAL COSTS VS RAW MATERIALS COSTS

Figure 4

TABLE 3

COSTS OF FURFURAL FROM BAGASSE VS. CORN STOVER

	Bagasse	Corn Stover
	In Millions of 1976 Dollars	
Raw Material	7.143	19.008
Operating Costs	16.248	16.248
Annualized Capital Charge	7.858	9.225
By-Product Credits	(10.298)	(9.555)
TOTAL	20.95	34.93
Cost Per Pound	$0.29	$0.39
Cost with Distribution at 30%	$0.38	$0.50

Then a few years later duPont discovered they could make tetrahydrofuran from acetylene and formaldehyde and they said to South Puerto Rico Sugar, "Well, find another customer."

Well, nowadays they have found new customers and furfural is short. Now they are using rice hulls. A new plant is being built by Quaker Oats near Houston that will use rice hulls in spite of the fact that you get a low yield and you have a lot of silica, 20% silica, in the material that you use. But the moral is, when you are dealing with an agricultural product the chemical firm would rather go find a nice, stable chemical source.

Now, of course, with Arab oil fluctuating up and not down, at least they know what they can count on. The price of agricultural products go up and they go down, and uncertainty is something that people making large investments do not like to deal with.

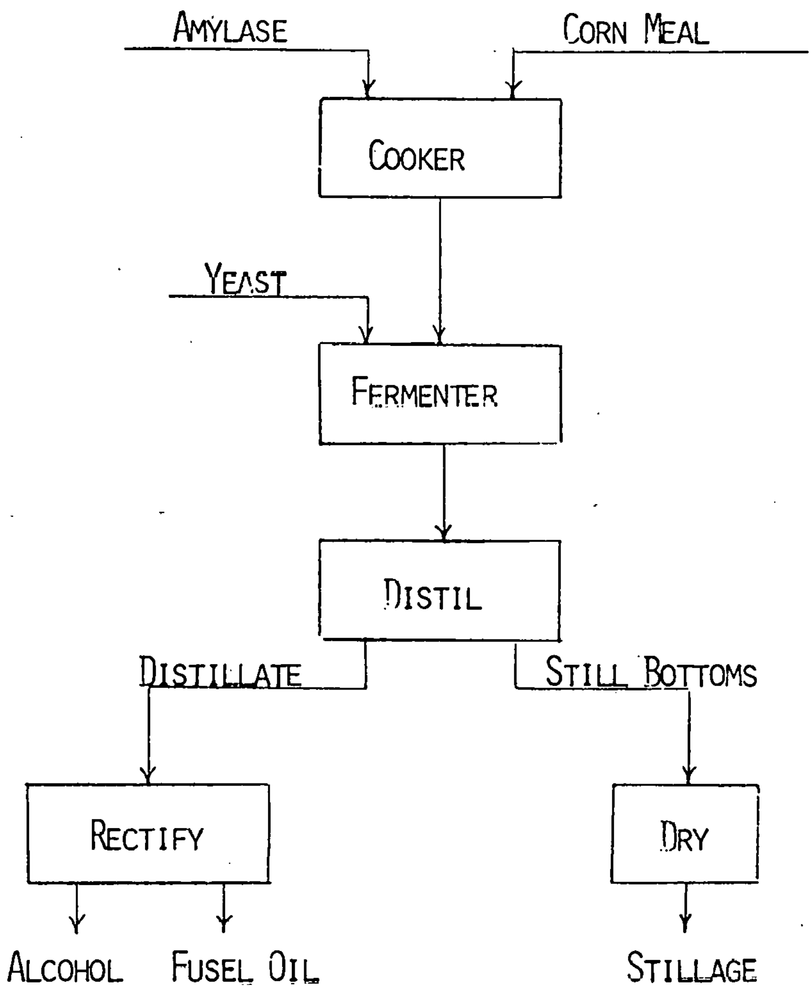
Now I would like to say something about ethyl alcohol. The price of ethyl alcohol distributed is now about $1.15 a gal. If it is bought directly on the spot it can be had for 80¢, but $1.15 is the published number that we have been working with. Over a billion pounds are produced annually which means according to our graph in Figure 2 it falls in the range of a large volume and low price commodity. Ethyl alcohol is used, as you well know, as a beverage and also as a solvent and a chemical intermediate. You can make ethyl esters from alcohol or the alcohol can be made into acid aldehyde which is then made into acetic acid, and you can make all sorts of chemicals from acetic acid. Ethyl alcohol once was used for making ethylene. Nowadays, it is made from ethylene. Ethyl alcohol could be made from grain or molasses if processing cost comes down.

Now, a number of things have made us wonder whether the cost of processing ethyl alcohol from grain or molasses is going to come down. We have heard about some new processes for making ethanol from grain or from molasses or from any sugar material. There is the so-called Anflow process that has enzymes tied up on a pipe and it changes the material as the material flows through the pipe. Professor Wilke has developed a vacuum process and there are all sorts of interesting things on the horizon. But the process that we are going to look at is shown in Figure 5.

In this process we take the corn meal and mix it with an enzyme that converts the starch into sugar, then we cook it. Then we add yeast and we ferment it. Next we distill it, and from the fermenter and from the distillation we get the spent grains. We can dry these and sell them for animal feed.

The distillate we run through another still to lower the water content down to about 5%. We have to do still one more distillation if we want to lower the moisture content beyond 5%. Professor Scheller has looked at ways of taking the stillage and instead of selling it for animal feed extracting a high value of human protein concentrate.

Another technique that can be used to improve the economics of this process is to remove the germ at the beginning of the process, and then squeeze the oil out of the germ and sell the oil for use in making margarine. The spent material goes then to animal feed.



CONVENTIONAL ETHANOL PRODUCTION

Figure 5

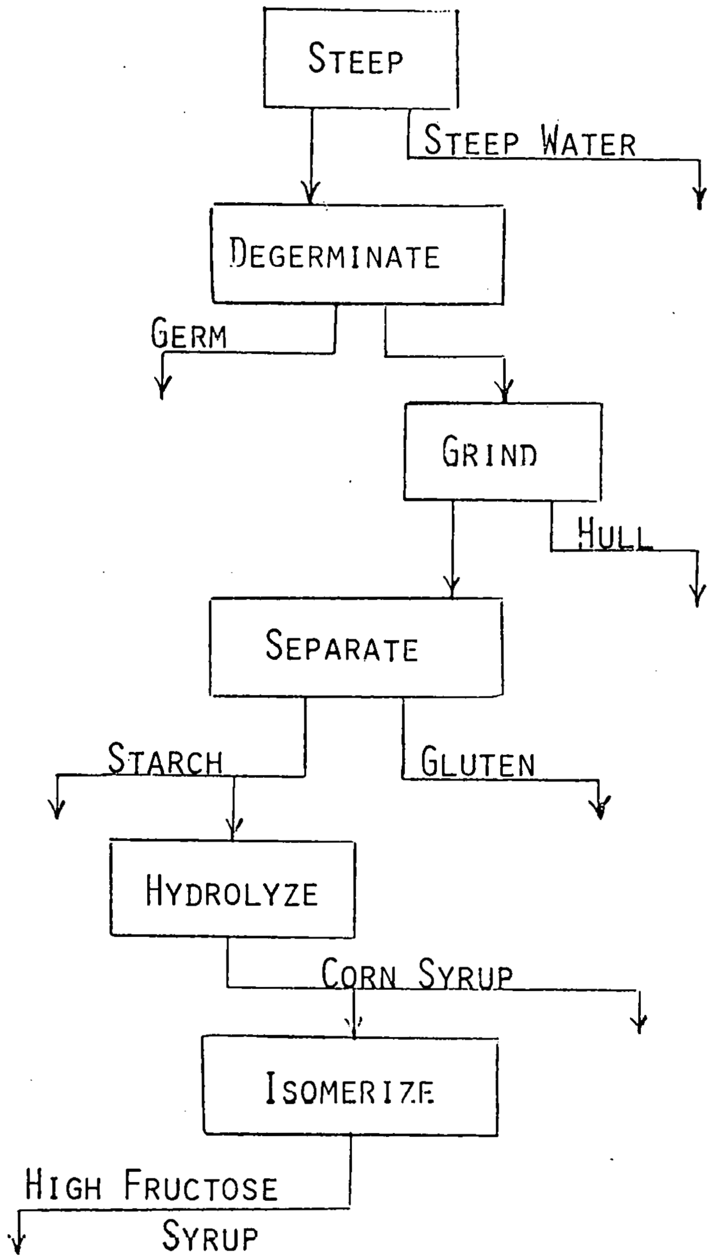
This process is a variation, on the conventional dry million process. There is another approach that starts with wet milling. In this process, shown in Figure 6, you take the corn and squeeze everything out of it you can. Then you steep it in water to loosen the germ and to loosen the hull. The steep water has some vitamins in it which you extract and sell. Next, you dry the steep water and use it for animal feed. You degerminate and take the germ off and, as mentioned earlier, you get the oil out of the germ and sell what germ is left over for animal feed. Then you grind the corn, and get the hull off. The hull is also sold for animal feed. Next, the ground starch is separated from the gluten, which is the protein part, and you also sell the gluten for animal feed. Since the gluten is yellow you can sell it to poultry producers. The reason poultry producers are interested in yellow feed is because you are not allowed to put dye in egg noodles, but you can put the dye in the chicken and get the dye to come through in the eggs and that colors the egg noodles yellow. The dye fed the chickens is the natural yellow color fo the corn. So corn gluten has a special value in poultry feed over what it would have, say, in hog feed or in ruminant feed.

The starch can either be sold or made into industrial starches or dextrins or whatever. Or it can be hydrolyzed to get corn syrup. The corn syrup is mostly a glucose solution having about 0.8 the sweetening power of sucrose. Somebody was clever and said, now let's make it as sweet as sucrose, and so they found a different enzyme which converts the corn syrup to a mixture of fructose plus glucose which is about the same composition as you have in honey. The fructose is sweeter than sugar and counterbalances the lower value for the glucose, also known as dextrose. So this fructose syrup has a sweetening power that is quite high.

Now,we could modify this corn wet million process as shown in Figure 7. Instead of separating the starch we would take the "easy" starch off and then we would ferment the startch that is left. We would take the gluten which is left over and distill it to sell for animal feed. There is a plant grain processing at Muscatine, Iowa, that uses this process and several others have been built. We decided to ignore this particular approach because we had to value the high fructose syrup and all of the different kinds of animal feeds available from the corn wet-million process. We figured it was better to run through our cost estimates the first time with the standard process.

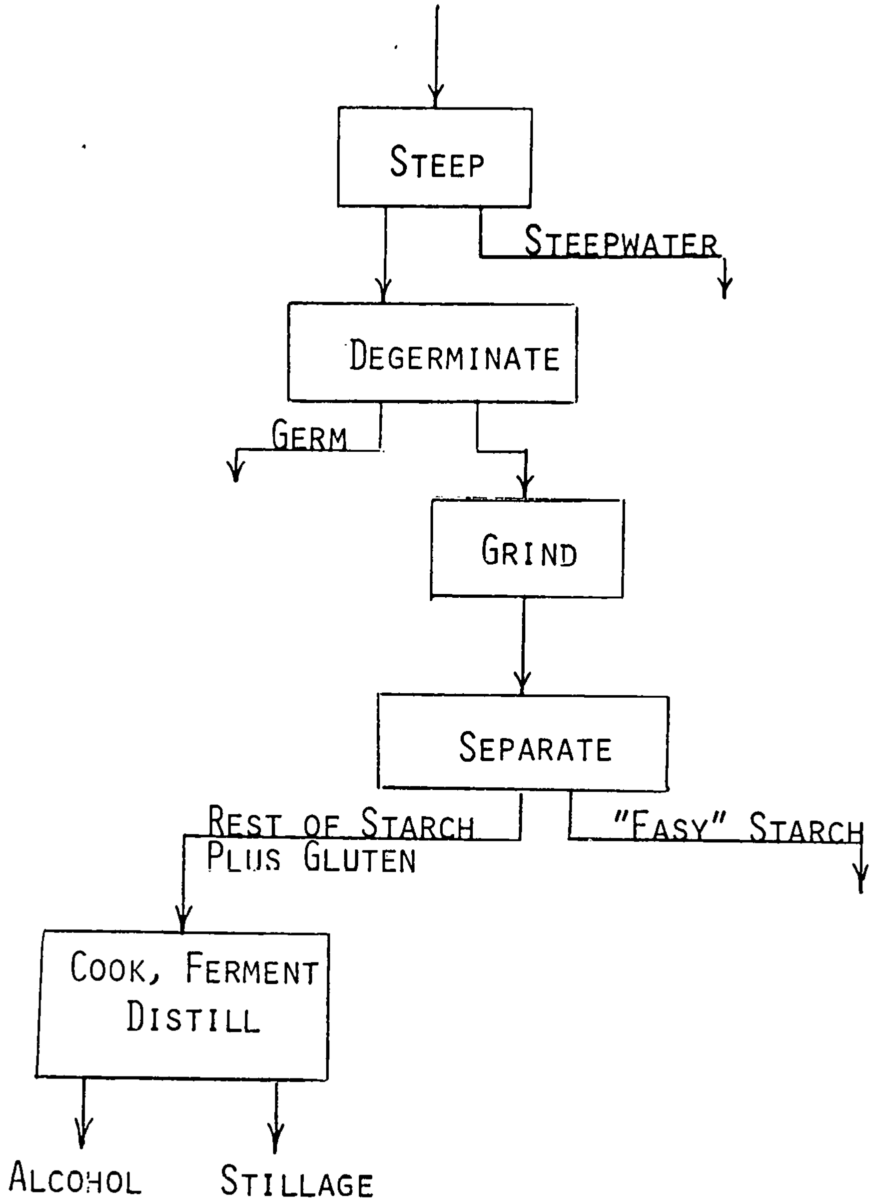
Table 4 shows the cost analysis for a plant that uses 24 million bushels of corn a year to produce about 70 million gallons of 95% alcohol. So with corn at two and a half dollars a bushel, we estimate the cost of ethyl alcohol or ethanol to be $1.18 per gal before the cost of the distribution or $1.53 per gal after distribution. We should compare our estimate of $1.53 with the $1.15 cost esimate that is listed in the Chemical Marketing Reporter. So you can see that cost of ethanol depends heavily on the by-product credit.

Figure 8 shows the results of our analysis on how the cost of ethanol varies with the cost of corn. You can see from the graph that even with corn for free ethanol would cost around 59¢ a gal and I do not think we will see corn as low as $2 again. Now, Professor Scheller has some ideas about using spoiled grain. Using spoiled grain would lower the costs, but it may affect the value of your stillage.



CORN WET MILLING

Figure 6



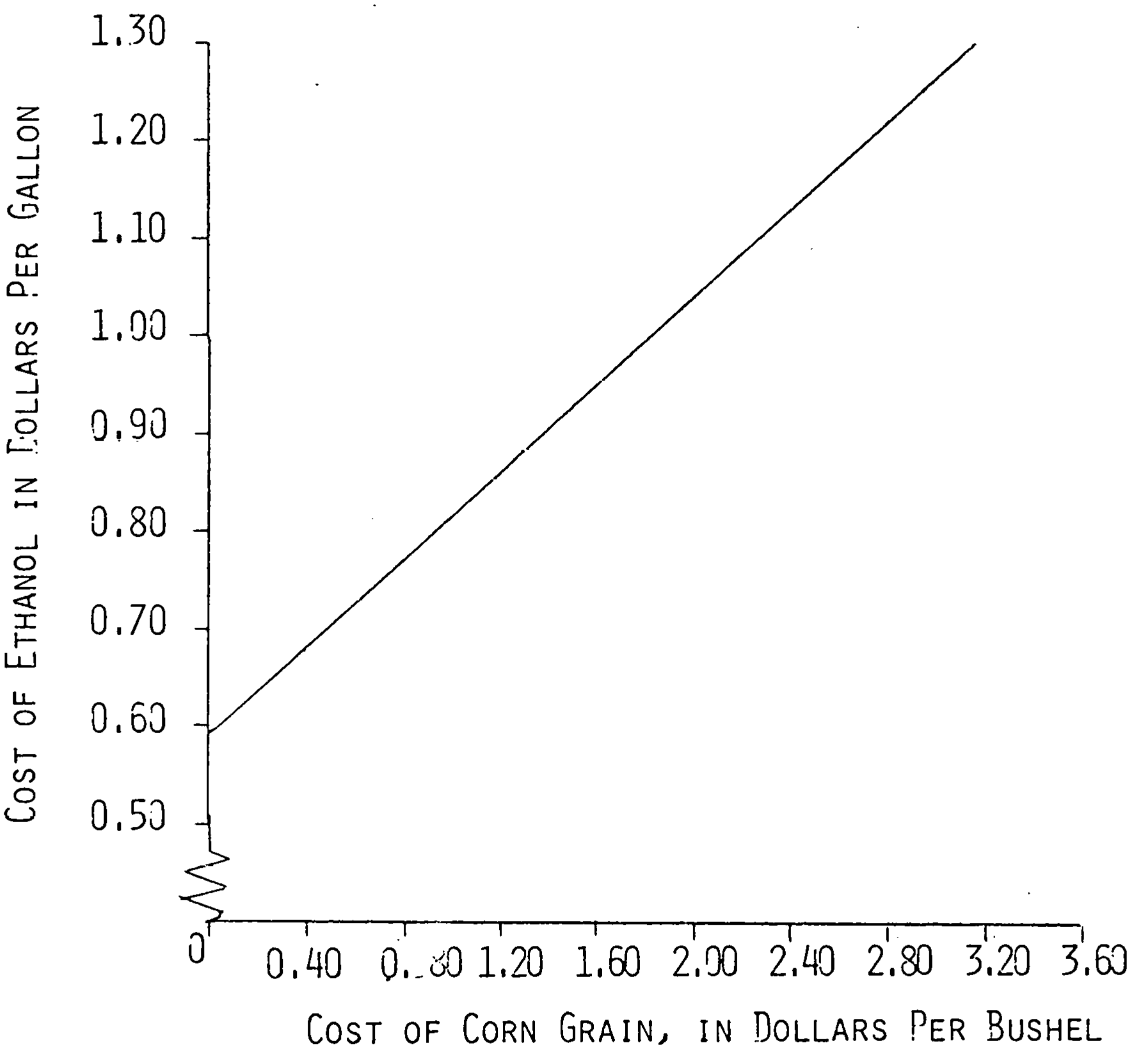
WET MILLING PLUS ETHANOL

Figure 7

TABLE 4

COST OF ETHANOL FROM CORN GRAIN

	Millions of 1976 Dollars
Raw Material, $2.50/bushel	60.73
Operating Costs	30.28
Byproduct Feed Credit, $105/ ton	(24.46)
Annualized Capital Charge	14.04
TOTAL	80.59
Cost per Gallon	$1.18
Cost with Distribution at 30%	$1.53



RAW MATERIALS COST VERSUS ETHANOL COST

Figure 8

Figure 9 compares distillage value with corn value. You see they parallel each other nicely until January 1, 1976. After that the two prices diverged.

Figure 10 compares the cost of ethanol with the credit you get for selling the stillage. So you can see the problems when dealing with an agricultural commodity. When the stillage credit is high, the process will produce ethanol economically; when the stillage credit goes down it will not.

In Table 5 we have compared the cost of making ethanol from corn with the cost of making it from sugarcane. The fermentable juices from the sugarcane cost 6¢ a lb. The process for sugarcane is the same as for corn. Notice the byproduct credit in the case of the sugarcane is much less because we do not have as much protein and we have more salts. So our cost for the ethanol comes out about the same from the two processes. The problems with using sugarcane is that we have to store the juice for 6 months whereas in the case of corn you can buy grain on the open market all year round and only have to store a week's worth. So you working capital with corn is much less.

So as a first approximation we show that the costs of making ethanol from corn and sugarcane are the same and that both costs are higher than current costs for making ethnaol from ethylene. Figure 11 compares the cost of ethanol with the cost of petroleum. From this graph we determine that oil would have to cost $20 a barrel before making ethanol from corn could complete with making ethanol from petroleum. And if we want to use the ethanol to make ethylene, oil has to get up to $35 a barrel, before it would be cheaper to do this than to make the ethylene from petroleum. And although not shown on the graph, oil would have to cost $85 a barrel before it would pay to burn alcohol from corn in an automobile.

<u>Question</u>: Yes, how accurate is your cost estimate? Can you say it is accurate to ± 5%?

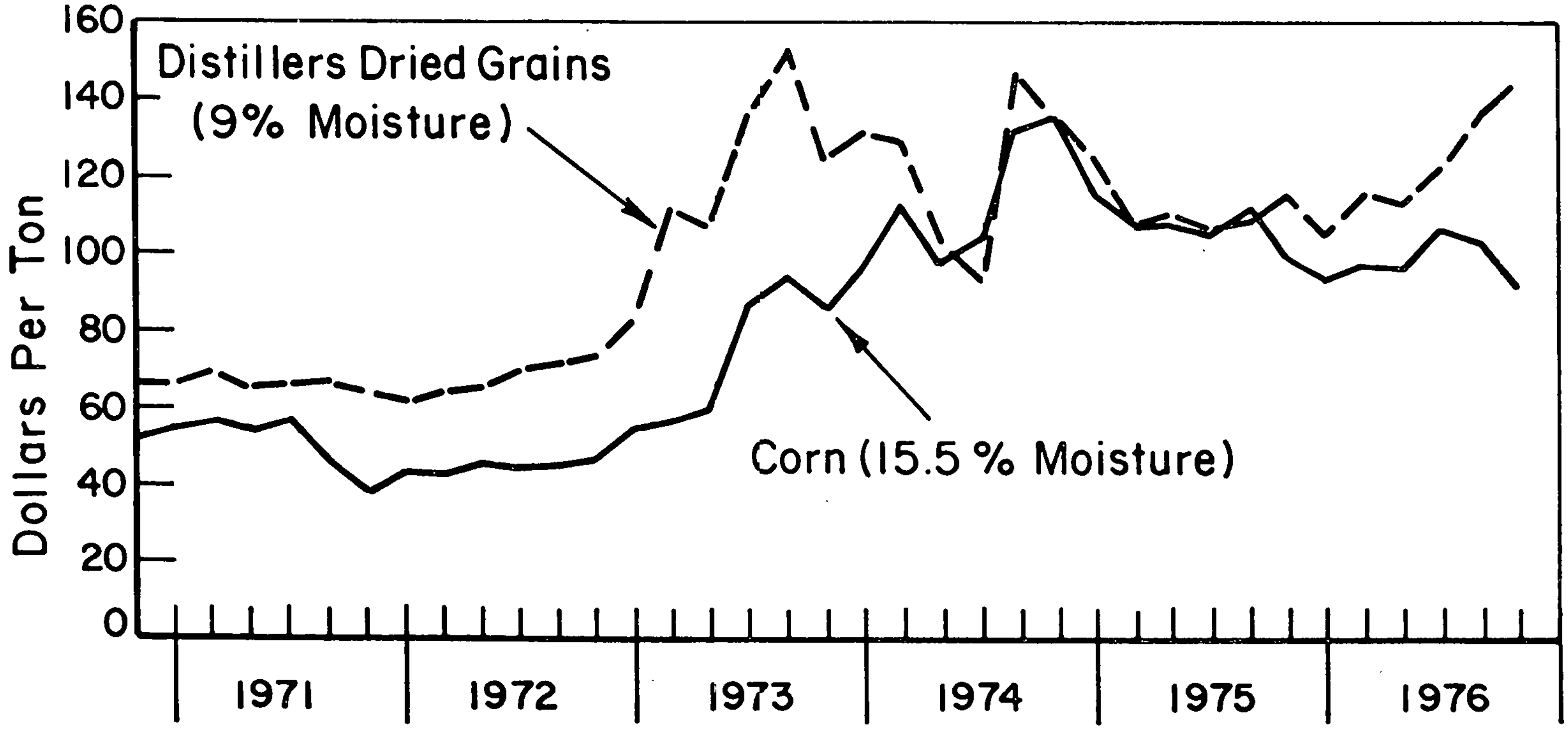
Dr. Sheppard: If you wanted the cost accurate to 5%, you would have to build the plant and then see what your results were afterward. These are engineering costs and they are off maybe by a factor of 50% on the high side and 30% on the low side. In other words, they are not very dependable until you build the plant yourself.

Now, Professor Scheller is getting bids presently on an alcohol plant in Nebraska and then we will know the costs better when it is finished.

We have not really done any engineering drawings on this. So our estimates are indicative kind of numbers.

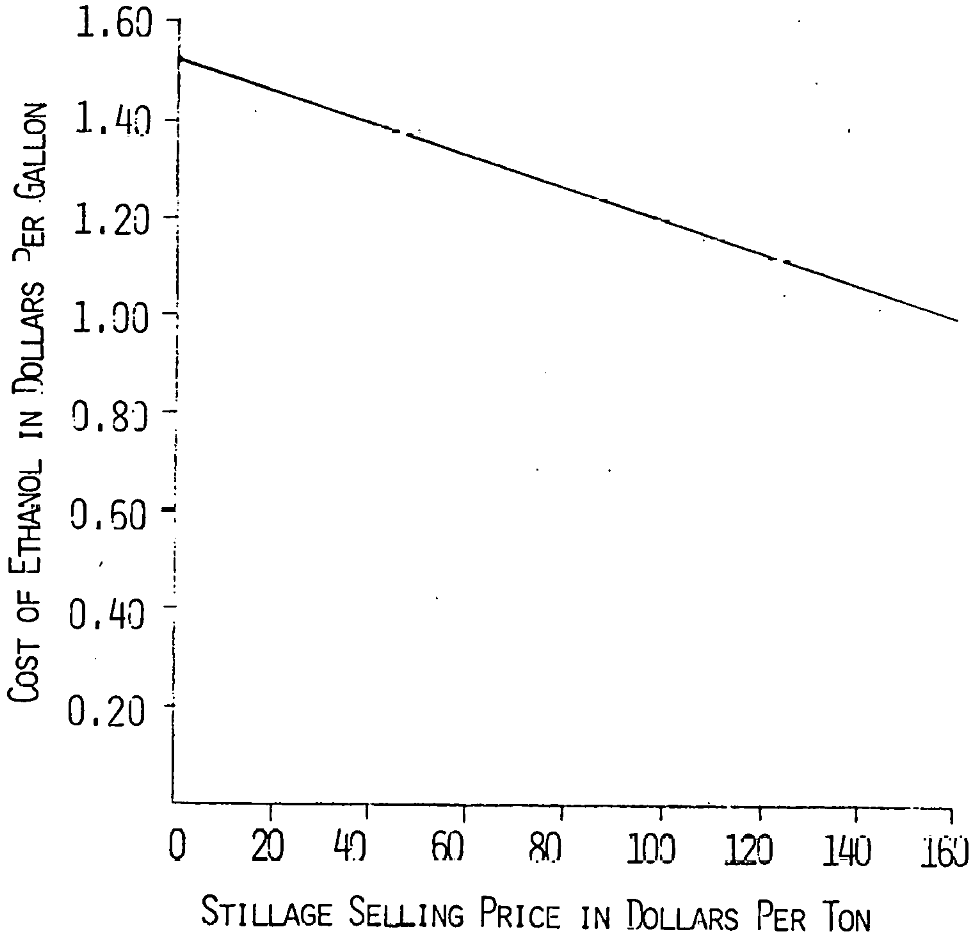
<u>Question</u>: Your distribution cost is 30%, does that include your turn-on investment?

Dr. Sheppard: Now, the cost of $1.18 for the gallon include the return on capital used in the manufacturing. The 30% is marketing charges including the profit on the marketing part of the enterprise. In other words,



AVERAGE MONTHLY WHOLESALE PRICES OF DISTILLERS DRIED GRAINS (DARK) AND CORN (NUMBER TWO YELLOW) AT CHICAGO

Figure 9



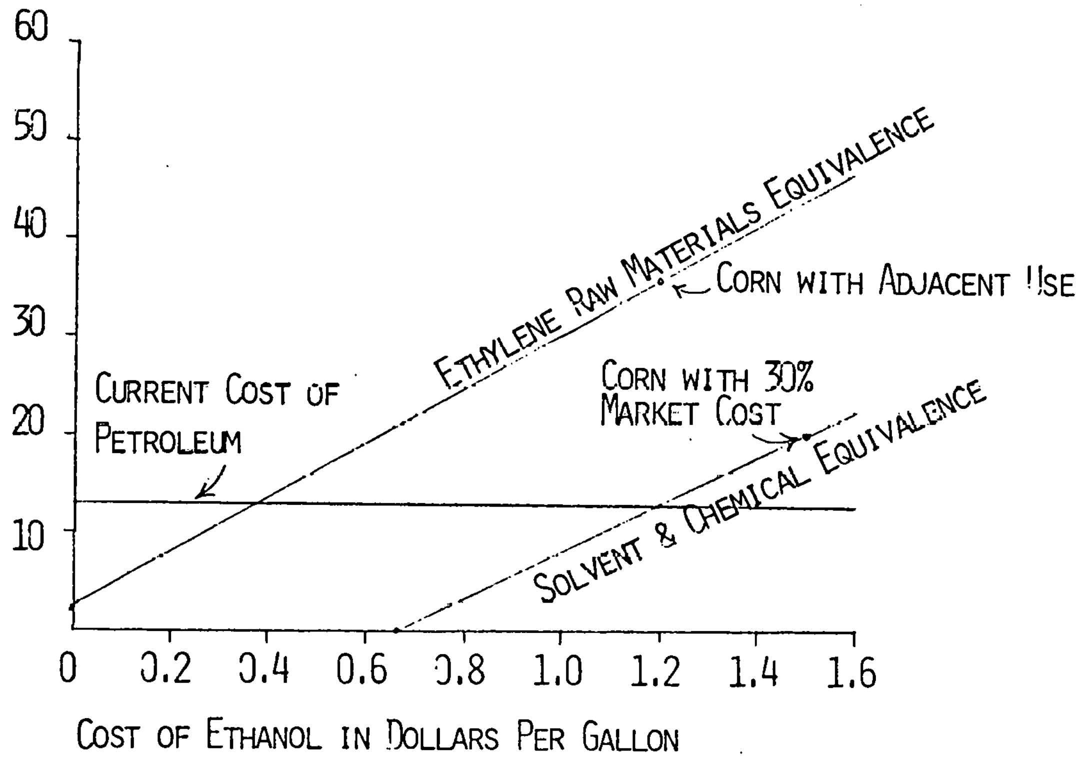
STILLAGE PRICE VERSUS NET ETHANOL COST

Figure 10

TABLE 5

COST OF ETHANOL FROM CORN AND SUGARCANE

	Sugarcane	Corn
	Millions of 1976 Dollars	
Raw Material	55.8	60.7
Operating Costs (Including Denaturant)	22.2	30.3
Annualized Capital Charge	14.9	14.0
Byproduct Credit	(13.4)	(24.46)
TOTAL	78.5	80.6
Cost Per Gallon	$1.14	$1.18
Cost with Distribution at 30%	$1.48	$1.53



SUBSTITUTION POSSIBILITIES FOR ETHANOL FROM FERMENTABLE SUGARS VERSUS PETROLEUM

Figure 11

you go to a solvent company and say, I want to buy the alcohol and he supplies you from the warehouse in your own town. And so he has the distribution and warehousing costs and a profit on that part of his business and it all totals to a 30% mark-up.

Question: It sounds a little bit high if that is what you are saying it is.

The other question I had was, how does your price here compare with the present rates for a fermentation grade ethanol, which is what you are looking at?

Dr. Sheppard: The fermentation grade ethanol, you mean sold for beverage purposes?

Question: Oh, no.

Dr. Sheppard: I do not know what the current price is. If you were a medicinal alcohol user and were able to buy it tax free, it would be about $1.20. You pay something for the bookkeeping because you have to keep it locked up and you have to have treasury guys there when you unlock it and thigns of that sort.

Question: You talked about the uses of ethanol. I know you can take propanol into propane, which is a motor fuel. Do you know how to get from ethanol to propanol?

Dr. Sheppard: Ethanol to propanol? Well, you can do it. You can use oxoprocess approach or you could make ethylene and then use the oxoprocess. There are ways of doing this. I do not think you would really want to. You could just burn the ethanol as it is as a motor fuel and it is perfectly fine. You would not want to spend another 50¢ to convert it to something that was just a little bit higher in boiling point.

Question: Does propane give you a longer range for vehicle use?

Dr. Sheppard: Yes, Detroit's approach would be put a larger gas tank in.

Question: Bill, I believe you said that you used $2 per million Btu for bagasse?

Dr. Sheppard: A dollar million Btu, lower heating value. And that, as you can well attest, may be a low number.

Question: That is a very low number. You come up with about $24 on your chart here, using 29¢ come up with about $24 per bone dry ton of bagasse. Now, that really is just fuel value. Now, you have got tremendous costs of storing it, retrieving it from storage, and getting it up to your plant or to your digester. So I think you have got to add quite a lot on to that to probably bring it up to the $36 you have for the stover. I do not know whether you included storage costs of the stover, but the storage and the retrieval costs are very high for these materials. I mean retrieval costs might be as much as $5 a ton.

Dr. Sheppard: This is, in a sense, built into our operating costs. Or we tried to build it into the operating costs. So we took the cost of freshly obtained bagasse as a raw material cost and then storing and handling and spraying it with water every now and then and worrying about a fire if you do not, and that sort of thing, we put into the operating costs. There is a philosophical problem that you have here. If your plant has a lot of bagasse it is a disposal problem and you design your power plant as an incinerator as well as a power generating unit. On th other hand, if you run short and have to buy fuel oil at $2 a million Btu or $3 a million But, then you say your bagasse is worth that much. Now, our $1 a million Btu sort of assumes that you can use low sulphur coal, which might be true in Louisiana but not true down in southern Florida. Now, what we are hoping in our sugar program is to find ways of getting more bagasse in, maybe bringing the leaves and tops and that sort of thing, so that we do not run short and do not have to buy external fuel oil.

Question: What was your capital cost for the plant?

Dr. Sheppard: Let's see, that was 69 million dollars for the battery limits cost, and by the time you threw in all the offsites and extras it was up to 117 million dollars.

Queston: I think that is low.

Dr. Sheppard: Notice, this is a rather large ethanol plant, 70 million gal a year. We use a scaling factor of nine-tenths. We started with a very complete equipment list for using sugar. Then we took Dwight Miller's numbers and we compared his with ours and they agreed, and so he is right. We looked at Professor Scheller's numbers and they were a little bit less, and so we did not use his, but we are giving him a chance to also talk.

The capital costs are about the same for all three approaches. It is just the operating costs that were lower in Professor Scheller's case. So at least the three of us agree on the capital costs.

Now, if you have better numbers--and I called ADM to try to get their numbers for their wet milliong one and I got a lot of confusion, which I think was intentional obfuscation.

Question: I think theirs is an easy starch process too.

Dr. Sheppard: Yes, it is, easy starch.

Do you want some more food for thought? Last year we used over 100 billion gallons of gasoline. Let's assume we could replace it with 100 billion gallons of ethyl alcohol and at 2.8 gal of gasoline per bushel, if you go through the calculation, it comes out to 40 billion bushels of corn would be required and last year we produced about 6 billion bushels of corn. So we would have to increase the amount of corn grown by six- or sevenfold in order to supply the gasoline market, which is about half of the petroleum that is used.

THE USE OF ETHANOL-GASOLINE MIXTURES FOR AUTOMOTIVE FUEL

Dr. W. A. Scheller

University of Nebraska

Consideration of the use of ethanol as an automotive fuel additive is as old as the internal combustion engine itself. Otto is said to have run his first engine on pure ethanol. In 1907 the U.S. Department of Agriculture published a report entitled "Use of Alcohol and Gasoline in Farm Engines." In 1926 in Britain, Ross and Ormandy published a paper on the use of alcohol fuel in internal combustion engines. Bridgeman published a paper in 1936 in industrial and engineering chemistry on the "Utilization of Ethanol Gasoline Blends," and in 1936 the U.S. Department of Agriculture published a booklet on "Motor Fuel from Farm Products."

This interest continued to a greater or lesser extent into the post World War II years and up to the present. Each time the price of grain has fallen to a low level there has been renewed interest in the use of grain alcohol as an automotive fuel additive and until recently this consideration has proven to be uneconomical because of the low price of gasoline. Not until late 1973 when the OPEC countries placed an embargo on crude oil shipments and increased its price by a factor of about 4 did ethanol derived from grain have the possibility of competing with synthetic ethanol (from ethylene) in the industrial market place and with an increased gasoline price it became an economical additive to unleaded automotive fuel.

PROPERTIES AND PERFORMANCE OF A GRAIN ALCOHOL BLENDED AUTOMOTIVE FUEL

Ethyl alcohol and gasoline are miscible in all portions. The presence of the alcohol in solution with gasoline also increases the water tolerance of the gasoline. Gasoline itself will hold only a few parts per million of water whereas a 10% mixture of ethanol and gasoline will tolerate upwards of 0.25% water (depending upon temperatures) before phase separation takes place. Thus, if normal precautions are taken in the refinery, during transportation, and at the service station the use of an ethanol-gasoline blend will insure the driver of a completely dry fuel system in his vehicle. To insure that water levels remain low in the fuel throughout the various stages of blending and handling we recommend the use of anhydrous ethanol as the alcohol component. Over 2 years of experience including severe winter conditions at temperatures as low as -35°F have been encountered in our

Nebraska two million mile gasohol road test program with no problems encountered from water phase separation. Gasohol is a registered trademark for a fuel mixture of 10% anhydrous ethanol and 90% unleaded gasoline which is being studied by the state of Nebraska.

In December 1974, the Nebraska Agriculture Products Industrial Utilization Committee in cooperation with the Department of Chemical Engineering at the University of Nebraska, the Nebraska Department of Roads and the Cooperative Refiners Association began a two million mile test program to compare the performance and properties of unleaded gasoline and gasohol fuel. To date, about one and a half million miles of driving experience have accumulated with no problems encountered. Properties of each blend of gasohol as well as the unleaded fuel used as the gasohol base stock are determined through ASTM analytical procedures. Drivers submit a weekly report on fuel consumption and miles traveled between fillings. The property and performance information presented in this report were obtained as part of the two million mile test program.

Octane number is an important property of automotive fuel. Ethanol is a component which as a pure component has an F-1 (research) octane number of about 106. However, in solutions of low concentrations ethanol displays an even higher blending octaine number. At 10 liquid volume percent ethanol in unleaded gasoline, this blending octane number is 134 on the F-1 scale. Figure 1 shows the results of a number of octane measurements as a function of liquid volume percent ethanol in the unleaded fuel. The scatter of the data points is within the precision of the octane measurement method. At the level of 10 liquid volume percent ethanol the F-1 octane number of the alcohol-gasoline blend will be 4.5 numbers higher than the unleaded base gasoline used in the blend. The F-2 (motor method) octane number is also increased. The octane number posted on pumps in filling stations is an average of F-1 and F-2 numbers and will be increased by 3 at the 10% ethanol level. As we shall see later this ability to increase octane number adds value to the ethanol because it permits a less costly base stock to be used for blending gasohol fuel of an octane number equivalent to unleaded fuel which is normally marketed.

A second interesting phenomena that has been found in blending gasohol fuel is that anhydrous ethanol and gasoline display a positive volume change on mixing at alcohol levels below about 16 liquid volume percent. Figure 2 shows the effect of ethanol content on mixture expansion. At 10% ethanol the mixture expands by about 0.23% while the maximum expansion occurs at about 12.5% ethanol and is equal to approximately 0.55%. Additional ethanol in the alcohol-fuel blend can not be justified economically on the basis of the expansion difference between the 10% and 12.5% concentrations.

FIGURE 1

EFFECT OF ETHANOL ADDITION ON THE F-1 OCTANE NUMBER OF UNLEADED FUEL

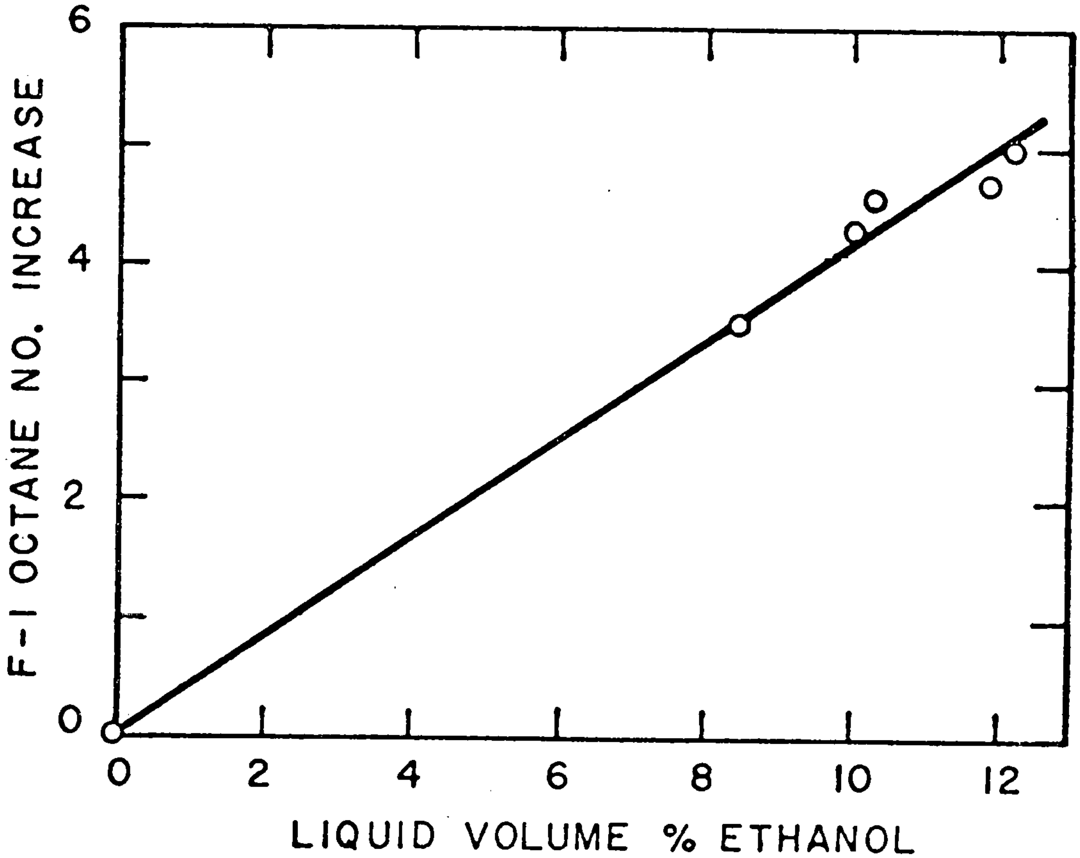
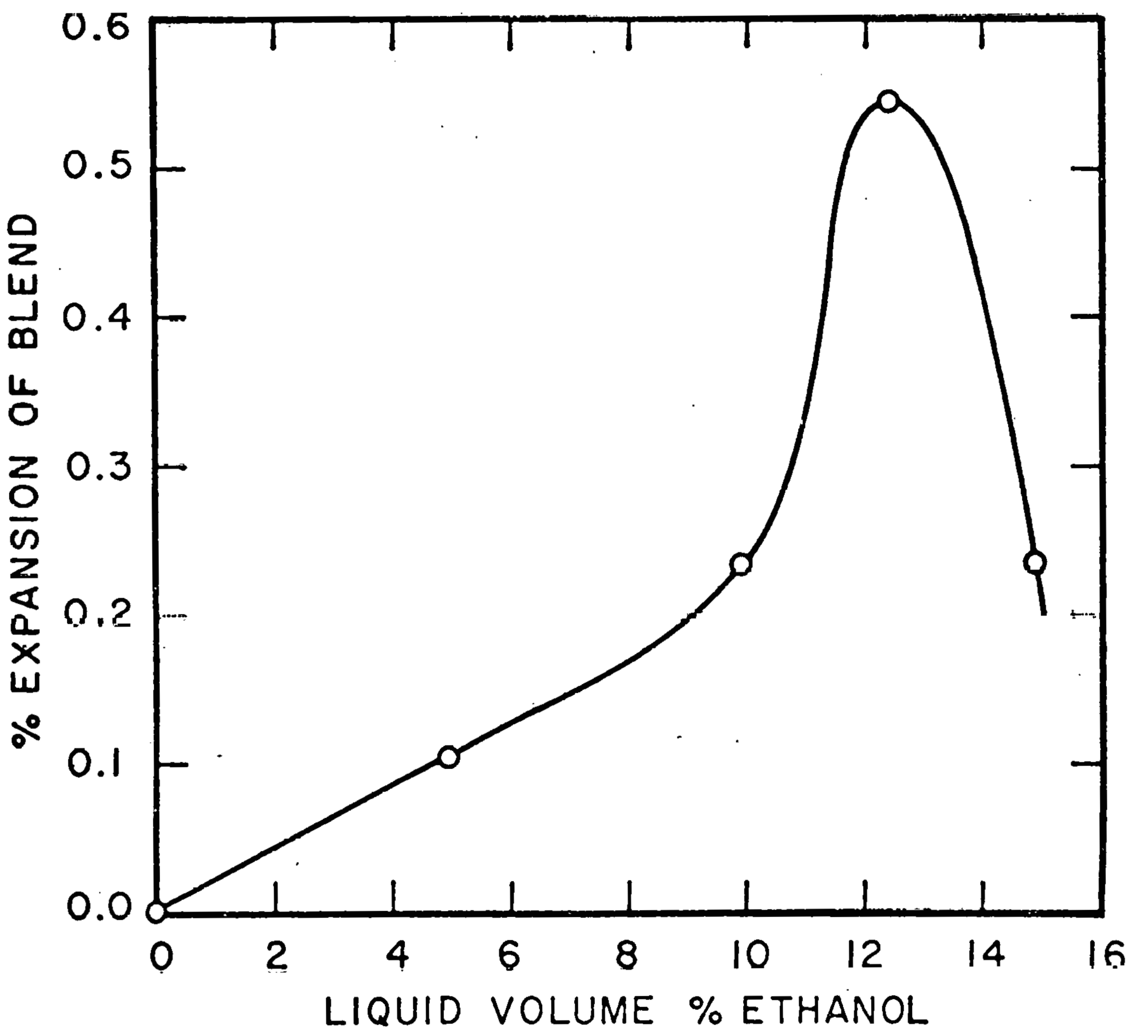


FIGURE 2

VOLUME CHANGE OF MIXING FOR ETHANOL-GASOLINE BLENDS



The normal boiling point of ethanol (172.9°F, 78.3°C) is sufficiently high that it has little or no effect on the vapor pressure and front end volatility of the unleaded gasoline used in blending gasohol. Numerous measurements have been made on unleaded base stocks and gasohol blends and it has been found that the Reid vapor pressure remains the same or shows a slight decrease of about 0.1 psi when the ethanol is added. The ASTM D-86 distillation is considered by the petroleum industry to be an important indication of the vaporization characteristics of automotive fuel. Figure 3 is a typical D-86 distillation for unleaded gasoline used as the base stock for gasohol fuel and for the gasohol fuel itself. Both fuels have the same volume percent distilled verses temperature relationship for the first 5% of the distillation. This supports the observation that little vapor pressure change is found when blending gasohol. Beyond the 5% point and up to approximately 60% distilled the gasohol fuel shows a lower distillation temperature (higher volatility) than the unleaded base stock. Beyond 60 liquid volume percent distilled the two distillation curves can again be considered to be identical. Drivers of the gasohol test vehicles have reported good performance with this fuel and also indicated good starting especially in winter months. On the other hand during the summers when the drivers have encountered temperatures of 100°F and higher during the day they have not experienced any vapor-lock problems even at attitudes close to 5,000 feet. It is believed that the lack of vapor-lock problems is the result of the front ends (up to 5 liquid volume percent distilled) of the distillation curves being identical for the two fuels. On the other hand, the improved performance and starting in the winter months is believed to be the results of the more volatile nature of the gasohol fuel between the 10% and 60% distilled points giving more efficient carburation and more complete vaporization of the fuel with better distribution in the intake manifold.

As mentioned previously a two million mile road test for the comparison of gasohol fuel with unleaded gasoline is in progress with approximately 1.5 million miles completed to date. Engine inspections, valve inspections, spark plug inspections, compression ratios, cylinder wear measurements, etc., indicate no unusual wear or deterioration of the engine as a result of using the gasohol fule. Data on fuel consumption and miles traveled have been keypunched and computer programs are being prepared for a complete analysis of the data. Figure 4 contains preliminary results for the vehicles in the test run operating from the North Platte, Nebraska, Office of the Department of Roads. In an effort to cancel out the effect of varying weather conditions we have plotted the ratio of the average number of miles traveled in a reporting period per test car using gasohol fuel to the average number of miles traveled in the same period per test car using unleaded fuel. On the Y axis is plotted the ratio of the gasohol fuel consumed in the reporting period per test car to the unleaded fuel consumed per test car in the same period. The data covered a period of approximately 1.5 years.

FIGURE 3

ASTM D-86
DISTILLATION

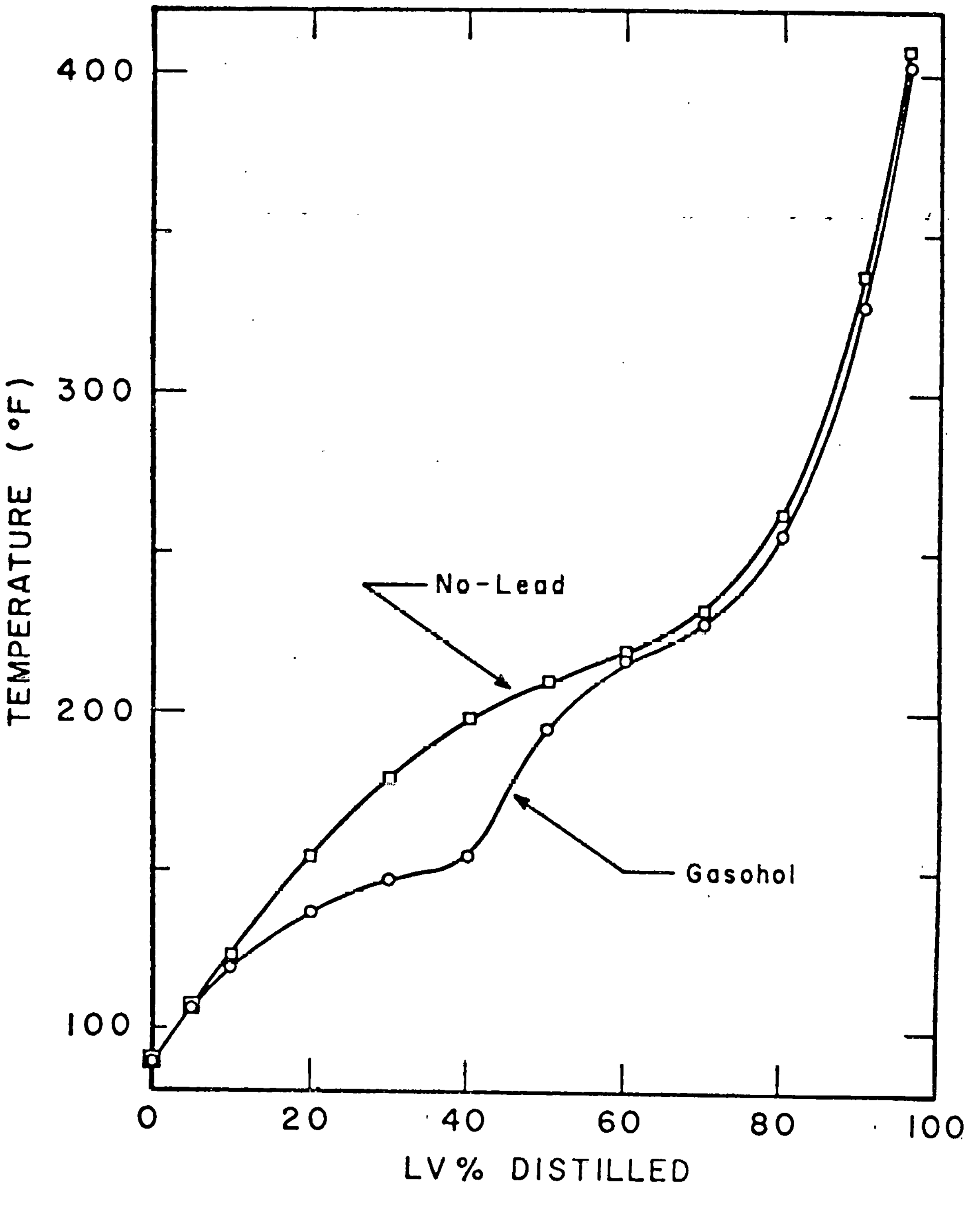
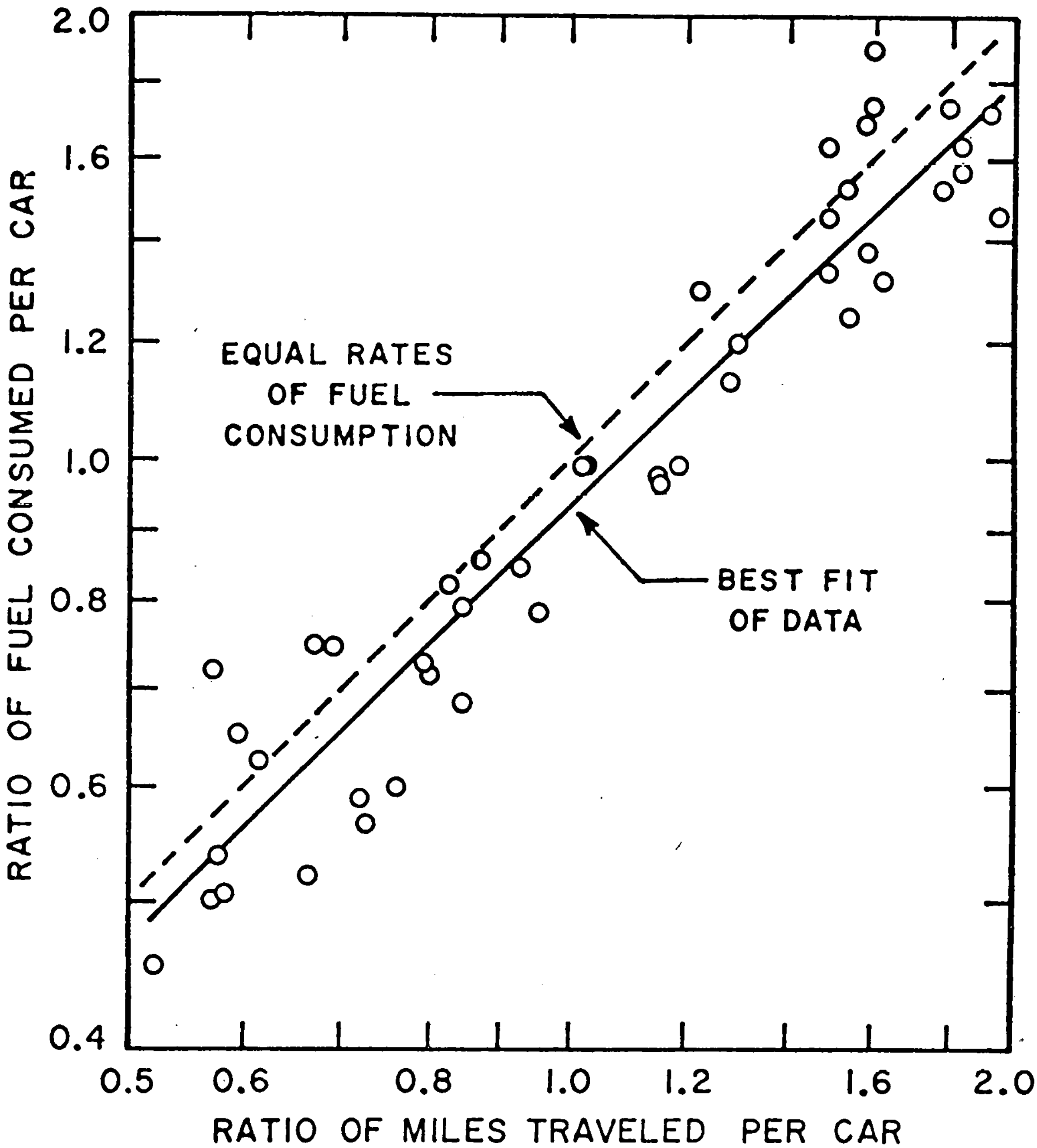


FIGURE 4

CONSUMPTION OF GASOHOL FUEL RELATIVE TO NO-LEAD AT NORTH PLATTE, NEBRASKA



The point of interest in this graph is that at which the mile ratio is equal to 1. It is at this point that we have the equivalent consumption of gasohol fuel relative to no-lead fuel. I have drawn a dashed line on the chart to represent equal rates of fuel consumption. The solid line on the chart is the best fit of a quadratic equation passing through the orgin (0,0). This best fit indicates that at an equal number of miles traveled the gasohol cars consume about 6.7% less fuel than the cards operating on unleaded gasoline. Applying Wilcoxon's signed ranks test to the data indicates that there is a 99 + % probability that the gasohol cars are consuming less fuel than the test cars operating on unleaded gasoline. Similar results have been found using data from Lincoln, Nebraska, test cars.

Thus, we see that there are at least three factors which tend to make alcohol a desirable component for blending with unleaded automotive fuel. These are the increased octane number resulting from alcohol addition, the positive volume change of mixing, and the reduced fuel consumption of gasohol fuel compared to unleaded fuel. In addition, the improved volatility of gasohol fuel provides added driver satisfaction through easier starting of the vehicle especially in cold weather.

VALUE OF ETHANOL AS AN AUTOMOTIVE FUEL ADDITIVE

Let us next examine the value that ethanol has as a component in automotive fuel. Each of the items to be discussed and their value are summarized in Table I.

The first item of value that 1 gallon of ethanol has in 10 gallons of gasohol is the value of the 1 gallon of unleaded gasoline which it has displaced. Based on current wholesale prices charged to the state of Nebraska for unleaded gasoline used in the two million mile road test program this figure is 38.56 per gallon of ethanol. But we mentioned previously that the unleaded base gasoline used in blending gasohol fuel could have a lower octane number than the unleaded gasoline which is marketed to the public. It is assumed that the gasohol fuel would be marketed at the same octane number as unleaded gasoline (92 F-1) and thus the base stock for gasohol could have an octane that is calculated to be 4.67 F-1 numbers lower (87.33 F-1). Published information on gasoline value verses octane number indicates that 1 octane number is worth about 0.45¢ per gallon of fuel. In 10 gallons of gasohol this represents a saving of 18.9¢ in the cost of the unleaded base gasoline which can be added to the value of the ethanol.

As mentioned previously the gasohol mixture has a greater volume that the sum of the component volumes by 0.23%. In 10 gallons of gasohol fuel this represents an added value of 1¢ per gallon ethanol. In the state of Nebraska the statutes provide that automotive fuel containing at least 10%

TABLE I

COMPONENTS VALUES OF COSTS CONTRIBUTING TO THE VALUE OF ETHANOL IN GASOHOL FUEL

		¢/gal ETOH
1.	1 gal of no-lead displaced by alcohol	38.5
2.	Credit for reduction in no-lead O.N. (1)	18.9
3.	Credit for expansion of mixture (2)	1.0
4.	Credit for 5% less fuel consumption (4)	32.0
	Subtotal	90.4
5.	Credit for Nebraska tax reduction (3)	30.0
		120.4

Notes: 1. $\left[92 - \frac{92-134x.1}{0.9} \right] 0.45 \times 9 = 18.9$¢/gal ETOH

2. $(36.8 \times 9 + 88.4 \times 1) \frac{0.0023}{1.0023} = 1.0$¢/gal ETOH

3. 3¢/gal fuel x 10 gal = 30¢/gal ETOH

4. 639 x 1.05 - 639 = 32¢/gal ETOH

agriculturally derived ethanol shall be taxed at 3¢ per gallon less than automotive fuel which does not contain ethanol. In 10 gallons of gasohol fuel this represents a reduction of 30¢ in tax which can be credited to the value of the ethanol. Adding these figures together gives a value for ethanol of 88.4¢ per gallon. If a credit for 5% less fuel consumption is added to the value of the ethanol i.e., 32¢ per gallon then the value of ethanol as an automotive fuel blending stock is $1.20 per gallon. Furthermore, since it is possible to adjust the mark-up permitted to the service station owner it is possible to use ethanol purchased at a value between 88.4¢ per gallon and a $12.0 per gallon to blend an automotive fuel which can compete with unleaded gasoline in the market place. Table II shows details for such a fuel assuming sale in Lincoln, Nebraska. All figures are based on recent prices paid for gasohol used in our two million mile gasohol road test program.

ECONOMIC OF ETHANOL PRODUCTION FROM GRAIN

The process for converting the starch in grain to ethanol has been known for over 4,000 years. The cost of a plant to produce anhydrous ethanol from corn or milo at the rate of 20 million gallons per year is estimated to be $23 million.

The cost of converting the grain to ethanol and cattle feed is approximately 31¢ per gallon of ethanol and the value of the byproducts is 44¢ per gallon of ethanol. Assuming that the $23 million required for the plant investment is obtained by securing private capital in the amount of $7 million and that a loan is obtained at 10% interest for the remaining $16 million and in addition $3.5 million is borrowed for the initial working capital the market price for ethanol can then be established if it is assumed that a 20% rate of return on the private investment capital of $7 million is desired. Table III contains information on the price of producing ethanol from corn or milo at different grain prices. As can be seen from the results in this table it is possible to produce anhydrous ethanol in the desired price range of 88¢ per gal to $1.20 per gal.

CONCLUSIONS

Grain alcohol has certain desirable properties when blended with unleaded gasoline such that its value as an automotive fuel component lies within the range of values for which ethanol can be produced from grain. Since the production of grain and its fermentation are less closely coupled to the price of crude oil than is the price of gasoline it further appears that

TABLE II

COMPOUTED PUMP PRICE FOR GASOHOL - 3 November 1976

Item	¢/Gal.	¢/Mile*
No-lead base gasoline, 34.3¢/gal	30.8	
Anhydrous ethanol, $1.10/gal	11.0	
Transportatin to Lincoln, Nebraska	3.3	
Station Mark-up	9.3	
Subtotal	54.4	3.5
Nebraska state tax (incl. 3¢/gal credit)	5.5	
Federal tax	4.0	
Pump price of gasohol	63.9	4.1
Current median price of no-lead gasoline in Lincoln, Nebraska (5 major brands)	63.9	4.3

* Assumes 15 miles/gal on no-lead and 5% better mileage for gasohol.

TABLE III

COSTS FOR PRODUCING ETHANOL BY GRAIN FERMENTATION

	Elevator Price, No. 3 Corn/Bu		Elevator Price, No. 2 Milo/Cwt.	
	$2.00	$3.00	$3.00	$5.00
Grain Costs (1)	67.5	101.2	57.8	96.3
By-Product Credit (2)	-43.7	-43.7	-45.7	-45.7
Net Grain Cost	23.8	57.5	12.1	50.6
Conversion Cost (3)	30.0	30.0	31.0	31.0
Interest on Loan (4)	9.8	9.8	9.8	9.8
Ethanol Cost	63.6 ¢/gal.	97.3 ¢/gal.	52.9 ¢/gal.	91.4 ¢/gal.
Depreciation (5)	11.5	11.5	11.5	11.5
Taxes (50%)	7.0	7.0	7.0	7.0
20% Return (6)	7.0	7.0	7.0	7.0
Ethanol Value	89.1 ¢/gal.	122.8 ¢/gal.	78.4 ¢/gal.	116.9 ¢/gal.

NOTES:
1. Assumes 75% marketable grain plus 25% distressed grain at 50% of the marketable grain price.
2. $120 per ton from corn and $116 per ton from milo based on protein content.
3. Based on Coal as the fuel source.
4. a) Plant Investment $23,000,000
   Working Capital 3,500,000
   Total Investment $26,500,000

   b) Private Capital $ 7,000,000
   Loan (10% interest) 19,500,000
   Total Investment $26,500,000

   c) Plant capacity is 20,000,000 gal/yr anhydrous ethanol
5. Depreciation is 10% per year on $23,000,000 plant investment.
6. Return is 20% on $7,000,000 of private capital invested.

grain alcohol will become more attractive as an automotive fuel additive as the price of gasoline and crude oil continue to rise. Since there is no shortage of starch in the world and since the use of by-product cattle feed from grain alcohol manufacture results in increased weight gain in cattle over that obtained with whole grain, the production of alcohol from grain does not remove needed food from the market place. Furthermore, since more ethanol can be made from low quality grains unsuitable for human or animal consumption and since the by-product cattle feed is suitable for use even more new protein can be introduced into the market place for human consumption.

Since grain supplies are not adequate to provide for the production of sufficient grain alcohol to blend 10% in all gasoline in the United States it is concluded that the gasohol program is a regional program which will find applications in grain producing areas of our nation.

Question: Have you ever throught about putting this down at New Orleans? That is where the spoiled grain is.

Dr. Scheller: No, I have not looked at a New Orleans location, but you are certainly right, there has been a lot of bad grain down there. And under the new standards I guess we cannot sell it as quality grain either.

Question: When you say that, through, then I want to get into the argument because the grain that you are talking about is so contaminated that I assure you you will not be able to sell the by-product grains. In other words, it will contain aflatoxin and all that. I am sure it will be condemned and you cannot take the credit that he is saying you can get by avoiding this.

Question: What do they do with the grain down there:

Dr. Scheller: You notice that we had net grain values after the by-product credit in the order of 12¢ or 20% per gallon of alcohol produced and if we consider that we get 2-1/2 gallons from a bushel, that means we would have to be able to buy this poor grain in the order of at something like 50¢ a bushel in order to be able to afford to throw away the cattle feed and not sell it into the marketplace.

Question: If all the gasoline sold in Nebraska was gasohol then who would pay to maintain the roads?

Dr. Scheller: Oh, this tax credit does not, as you saw, take away all of the road taxes. On the other hand, there is also a bill in the legislature to raise the gasoline tax 1¢ per gal. I am sure that we should view this tax credit as only an intermediate incentive to developing an alcohol blended fuel and that as the price of gasoline continues to climb that we should expect that this tax credit is going to back off until we are in a position where the addition is competitive.

Question: Having commented very favorably on the road test program, the economics, the availability of the grain, my question is, is the state of Nebraska or the state plus the private sector near to investing in a plant or plants of the type you outlined?

Dr. Scheller: Yes, on the 10th of January articles of incorporation were filed with the Secretary of State of the state of Nebraska to incorporate the Nebraska Grain Alcohol and Chemical Company, a private enterprize, with the announced intention of building a 20 million gallon per year grain alcohol plant in Nebraska. As you can tell from the name of the company, in the articles of incorporation is also the intention of producing other chemicals and also carrying out the permission to carry out any business legal under the Nebraska statutes.

But the incorporators, the directors of the firm, have made preliminary contacts with underwriting and brokerage firms. The plans and necessary information are being developed to obtain SEC clearance for the sale of stock. When this clearance is obtained, why, a stock sale will be made and the balance of the funding will be borrowed. For example, the plant is eligible for industrial development administration bonds, so long as they locate in a community where the community also qualifies, and so forth.

Incidentally, to put this in perspective, I was on a site visitation last Monday to a town in Butler County, Nebraska. Butler County's grain production is 8 million bushels per year. It is not assumed that if the plant were there it would buy all the grain in the county, but to put this thing in perspective we are talking about an amount of grain that is about equivalent to the production of one county in the grain producing areas of the state.

THERMOCHEMICAL PROCESSING OF CORN

J. L. OTIS

BATTELLE COLUMBUS LABORATORIES

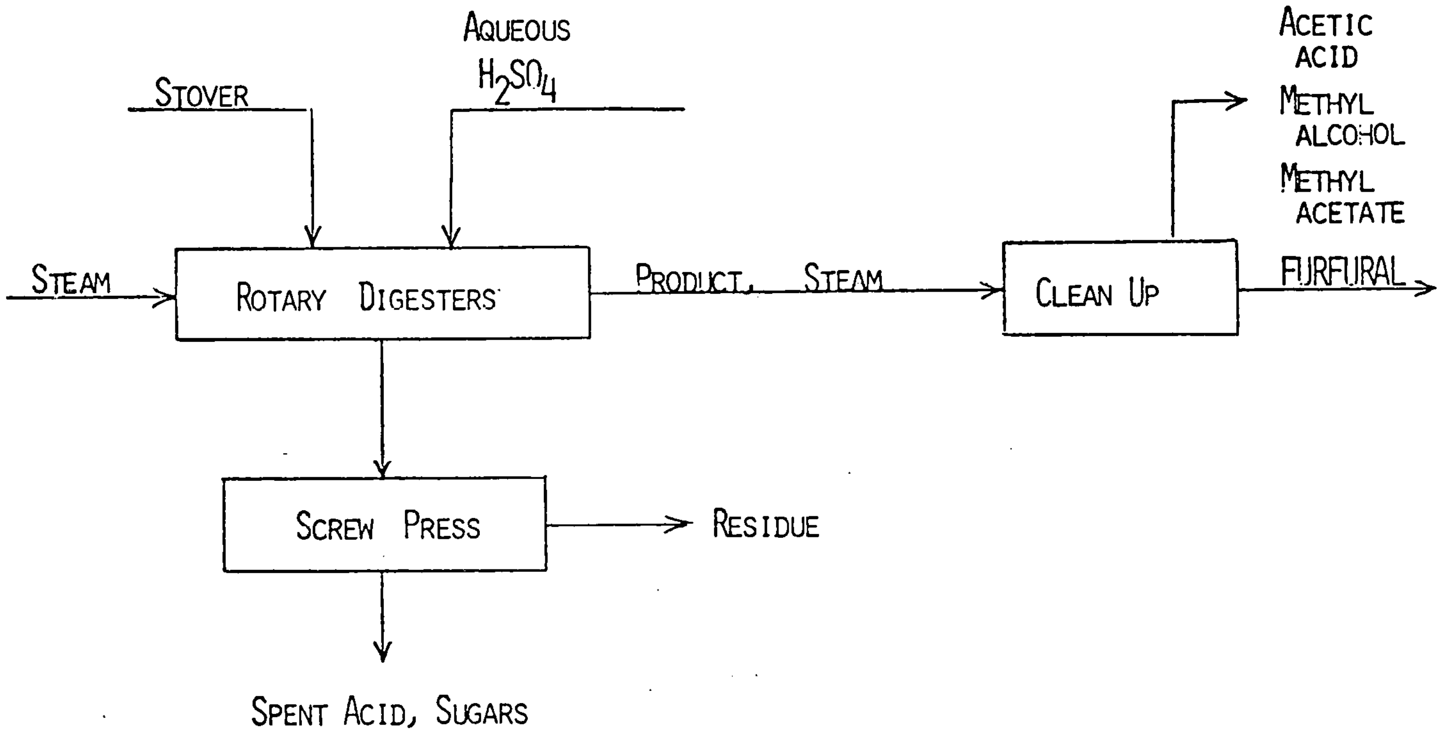
Dr. Sheppard and Dr. Scheller spoke about what can be done with corn products and residues, for example, furfural, ethanol and gasohol. My speech is somewhat a continuation of the same subject. We will look at what else we can do with these materials. I will be discussing some of the thermochemical conversion processing of these materials.

The feedstocks that I'm going to be talking about are of two types. One is the corn stover, the residues typically left in the field. Another one is the residue from furfural manufacture which Dr. Sheppard previously discussed. I will be looking into (1) power generation from these materials, (2) conversion to synthesis gas, (3) the various products that can be produced from these materials, (4) some description of the synthesis gas processes, and (5) the conversion processes to the various products that can be produced from the synthesis gas. We will be talking basically from an overview point of view. We will not be discussing very many details at all.

In the area of power generation, which is my first subject, in order to obtain good thermal efficiency we feel as though we must reuse the steam in other processing, so in these calculations for the most part we will see a major byproduct, steam cracking. As we will show you from the cost data, generally the economics for power generation from stover appear to be relatively poor. However, when we turn our attention to the utilization of the residue generated from furfural manufacture, we do find that the economics turn out to be much more favorable. However, when we do take a look at furfural, we find that there is only a few plants that can really be built to supply the rather limited needs of furfural at the kinds of economics we are showing here today.

Figure 1 shows the furfural process. The residue that we are talking about using for power generation is the residue from the screw press out of the furfural manufacturing process.

In Table 1 we take a look at the economics for the power generation from stover. We began by assuming we would use 1,522 metric tons per day dry basis weight. We valued this at $40 per metric ton. The economics of stover collection may prove out to be that we might have assumed a modestly lower number for the value of the corn stover. The scale of plant that we are talking about is only able to produce 39 megawatts. With stover valued at $40 per ton, a very major cost element in the annual operating cost is



FURFURAL PROCESS

Figure 1

TABLE I

POWER GENERATION FROM STOVER

STOVER: 1522 METRIC TONS/DAY
$40/METRIC TON

POWER: 39 MEGAWATTS

ANNUAL COSTS:	MILLION DOLLARS
STOVER	20.09
OPERATING	3.96
CAPITAL CHARGE	5.30
STEAM CREDIT	(-10.24)
	$19.11

POWER COST: $0.061/KWH

BY-PRODUCT STEAM AT $2.28/1000 POUNDS

* * * * * * * * * * * *

IF NO BY-PRODUCT STEAM REQUIRED

POWER: 68 MEGAWATTS

COST: $0.055/KWH

the $20 million for the stover. Our operating costs are a small factor, as is the capital charge. And we are taking a rather large strain credit of roughly $19 million per year.

Given these values, we compute a power cost of 61 mills per kw-hr, which is relatively high. As a point of interest, in this case we are taking steam off at 50 pounds and also 20 pounds with a byproduct credit taken as $2.28. That appears about right.

On the other hand, if we had not taken any byproduct steam out of the plant at all, we could have produced with the same material, same basis, about 68 megawatts, with a cost of around 55 mills per kw-hr.

Table 2 is the same type of table where we have computed the cost of power generation from the furfural residue. Now, you will recall that Dr. Sheppard valued the residue that he took out of the furfural plant at roughly $1 per million Btu's. Well, these are the kinds of numbers that I have shown on this particular table. We have assumed we would use the residue from making furfural out of 1,522 metric tons of stover. Our yield of residue is roughly 70% of that total. The residue contained 35% moisture and we valued it at $1 per million Btu's producing 27 megawatts. You will recall in the other table a major portion of our cost was the cost of stover. In this analysis it's much smaller. Again, we took a major steam credit, giving us an annual cost of $5.65 million with a power cost of 26 mills per kw-hr and our byproduct steam has been valued herein at $2.87 per thousand pounds.

Now, this steam is actually taken off at 150 lb per square inch and is reapplied directly into the furfural process, so we can, because of the higher pressures that we are employing here, value the steam at much higher value per thousand pounds.

Well, when we go into thermal conversion processes what are the products we get? In synthesis gas the real products that you are looking for are carbon monoxide and hydrogen. Unfortunately, you end up with some water and carbon dioxide in limited quantities. In biomass conversion, there is one nitrogen produced. A little bit of hydrogen sulfide is produced, and depending on the process employed, various quantities of low molecular weight hydrocarbons such as methane, ethylene and ethane are produced.

In general for the conversion of the synthesis gas to products like methanol and methane, you do not want the nitrogen in your gas. With ammonia you do want some nitrogen in your gas. However, if you used air directly, you would produce and handle too much nitrogen in that material and the process really wouldn't work, so this is why we want to avoid producing nitrogen with the other gases. The products that we can produce from the synthesis gas include ammonia, methanol and methane.

TABLE II

POWER GENERATION FROM FURFURAL RESIDUE

FURFURAL RESIDUE: FROM 1522 METRIC TONS/DAY STOVER
$1/MILLION BTU

POWER: 27 MEGAWATTS

ANNUAL COSTS:	MILLION DOLLARS
RESIDUE	5.05
OPERATING	3.06
CAPITAL CHARGE	4.71
STEAM CREDIT	(-7.17)
	5.65

POWER COST: $0.026/KWH

BY-PRODUCT STEAM AT $2.87/1000 POUNDS

Now, what is it that we want for manufacture of chemicals such as ammonia, methane, and methanol? Well, we want relatively high ratios of hydrogen to carbon monoxide. With ammonia we want no carbon monoxide ending up in the stream. With methane we want a ratio of 3 parts hydrogen to 1 part monoxide. With methanol the situation is a little bit different, we prefer a ratio of approximately 2 to 1 of hydrogen to carbon monoxide. As you can see, we do have to search for obtaining the right ratio of these two primary components when we apply our conversion process to the end product. Fortunately, there is the water shift reaction, which is a relatively low cost process, to give us the right ratios.

It's preferable for running the water gas shift reaction to have the proper ratios and conditions of pressure, temperature and moisture content in order actually to operate the water shift reaction.

Well, what do we want when we go to fuels? Well, again we want Btu's, which is another way of saying yield. We also want the yield for the chemicals. We do want to end up with adequate pressure when we are through producing our fuel to actually forward the fuel to the final user of the proudct. And in order to have a relatively high net heating value, and for proper burning characteristics, we do want to produce a relatively dry material. That's not quite as true as when we were looking at the chemicals and we need some water to run the water shift reaction.

We have looked at several candidate synthesis gas processes. We have looked at the Purox moving bed, which is a Union Carbide process, we have looked at the Pullman-Kellogg molten salt process, the Koppers-Totzek fluidized bed, the Bailie-Fluidized Bed process, and the CO_2 Acceptor process.

To the extent that we have studied these processes to date, our conclusion is that there are really no clear winners or losers in this. We end up with a lot of yes, it looks favorable, and there are these advantages, but there are these other problems. So with almost all of these processes we have a "yes, but" situation and really the only way that we can really establish what process would work best is by some real pilot plant work. We have looked at these five processes. There are quite a number of others that might be possible and all we have done is sample those that we feel are the most likely.

I might mention that most of these processes are basically pool processing types of synthesis gas processes. When we look at stover or furfural residue as feedstock it does have some advantages. It is a relatively fine material. Therefore, we end up with a higher reactivity basically than what one might find with a rather hard granular type product called coal.

Conversely that same fluffiness problem also turns out to be one of the major disadvantages. We have heard that in some cases there is concern that this fluffy material is very likely to blow right out of the reactor or out of the gasifier. So some of the people that are most acquainted with out processes are quite concerned about whether or not we can really handle these materials.

Another disadvantage of the stover or furfural residue is its relatively high moisture content. By and large there is a little bit too much moisture there. We have considered some various types of drying processes for the gas.

Figure 2 is a flow sheet of the Purox process. The material comes down through a feed hopper through a couple of seals and drops into a shaft furnace that is a gasification zone. The gas is taken off from here and moved into a gas cleaning train. The primary gas that we introduce in this process is oxygen. It goes through a combustion zone, burning the char, and eventually works its way up countercurrent to the falling solid material and on over into the gas cleaning train.

The Purox process operates at roughly atmospheric pressure. As is implicit from the diagram of Figure 2, an oxygen plant is required. And the way that it's been proposed to operate the Purox process is with a water quench that drops the temperature of the gas to roughly 180°F. As a consequence one does remove much of the moisture that was generated in the hydrogasification during the water quench reaction.

As I believe I mentioned before, the Purox process has been developed by Union Carbide. They have operated a 250 tons per day demonstration plant in South Charleston and are proposing the installation of a plant to be operated on municipal solid waste in Seattle, Washington, to produce ammonia, according to our most recent understanding. Again, we are concerned about a fluffiness problem. However, Union Carbide feels that this is simply a design problem that can be solved.

What kind of compositions do we have coming from the Purox process? Table 3 shows on a dry basis the concentrations of various products. As I mentioned before, what we want to produce is a high yield of the combination of hydrogen and carbon monoxide and hopefully at lesser concentrations of carbon dioxide. Production of hydrocarbons is nice if you are producing methane. However, they can work to your detriment if you are producing ammonia or methanol, and must be removed in order to operate the proper conversion process in these kinds of concentrations. Hydrocarbons up to about 5% are reasonable, but when you begin to exceed about 5% hydrocarbons it does begin to get sticky because of the way the processes act.

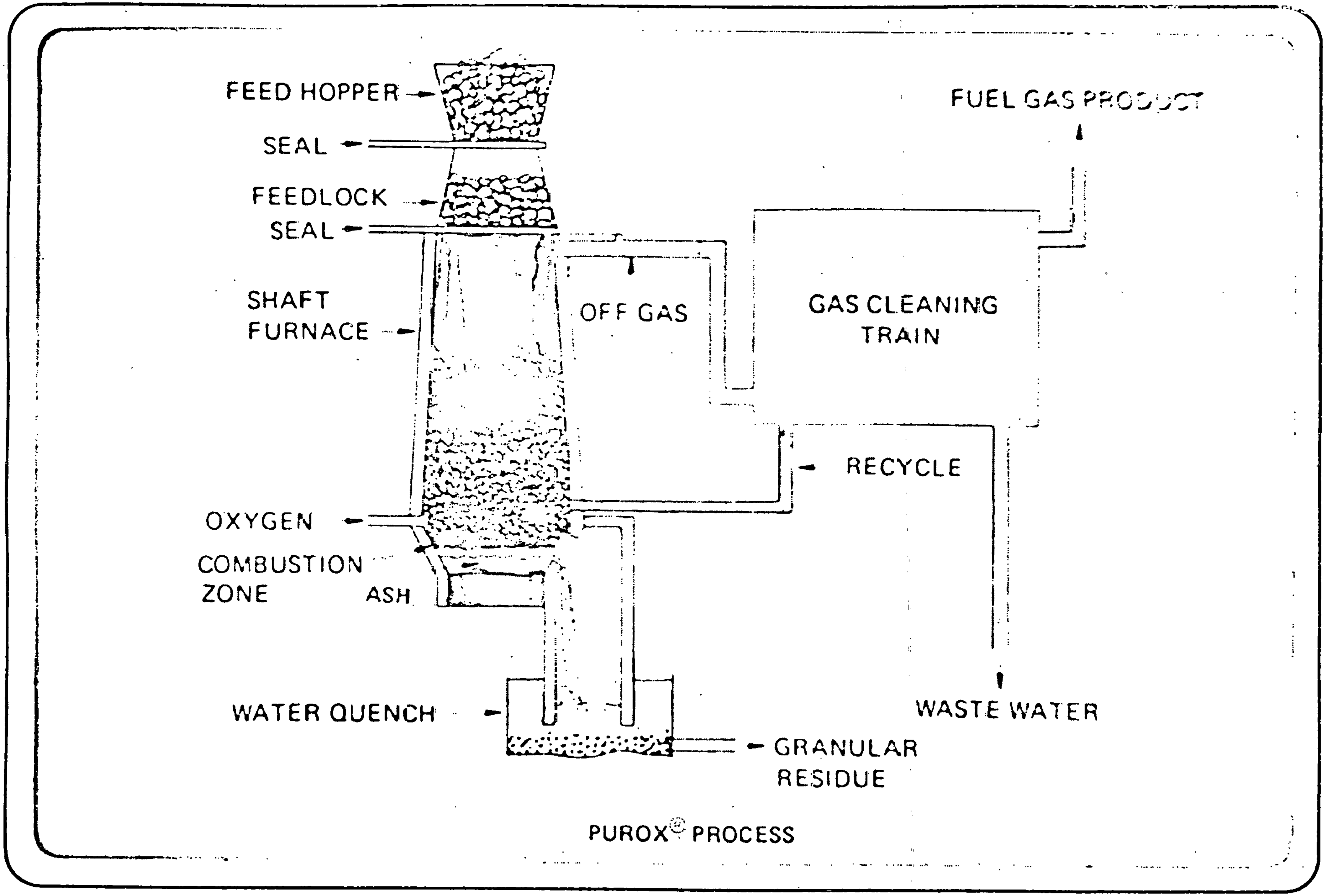

FEED HOPPER
SEAL
FEEDLOCK
SEAL
SHAFT
FURNACE
OFF GAS
GAS CLEANING
TRAIN
FUEL GAS PRODUCT
RECYCLE
OXYGEN
COMBUSTION
ZONE
ASH
WATER QUENCH
WASTE WATER
GRANULAR
RESIDUE
PUROX© PROCESS

Figure 2

TABLE III

SYNTHESIS GAS COMPOSITION FROM PUROX® PROCESS, MOLE PERCENT

	Stover
CO	45.1
H_2	28.2
CO_2	16.1
Hydrocarbons	10.2
N_2	0.4
	100.0
Net heating value BTU/SCF	340

We refer the the gas produced from the Purox process as a medium Btu gas with heating content of roughly 340 Btu's per standard cu ft.

What kind of economics do we have from the Purox process? Table 4 compares the costs of producing synthetic gas by the Purox process from stover and from furfural residue. The figures shown on a wet basis with the moisture content for stover at 20% and with the furfural residue at 35%. All the processes that I'm going to be describing for these kinds of synthesis gas processes have a fixed quantity of carbon monoxide plus hydrogen in order to operate our conversion processes that we will discuss later on.

In terms of millions of Btu's produced per day, both materials produce the same amounts. The major difference in these figures from Table 4 is the cost of the raw material. The difference in the cost of the stover and the residue is more than a factor of 2 because of the way we valued our furfural residue. The major difference in gas cost in terms of dollars per million Btu's, is that gas from furfural cost $3.05 and the gas cost from stover is much higher than that at $4.95.

The annualized capital charges, are identical to those as mentioned by Dr. Sheppard. We have included sinking funds to return principal to both equity and debtholders, 14% return on investment, and an 8.75% return on the interest of the 60% debt.

Our cost analysis for synthetic gas from corn stover assumes that the corn stover cost $40 per ton. At this price, the gas cost $4.85 per million Btu's. Figure 3 shows the sensitivity of the final gas cost as a function of the raw material cost. For example, had we chosen $20 per ton for corn stover the cost of natural gas becomes a much more favorable $3.40, which is beginning to come close to the numbers that we had with the furfural residue.

I would like to show you another process referred to as the Kellogg's molten salt process. Figure 4 is a schematic outline of how this process works.

The feed is fed into a molten saltbath for very intimate mixing and complete gasification. This process is also oxygen blown. On economics this process seems to be very comparable to the Purox process.

The unique thing about the Kellogg molten salt process is that it does come out at high pressure temperature and, therefore, because of the way it behaves we end up with a lot more moisture content.

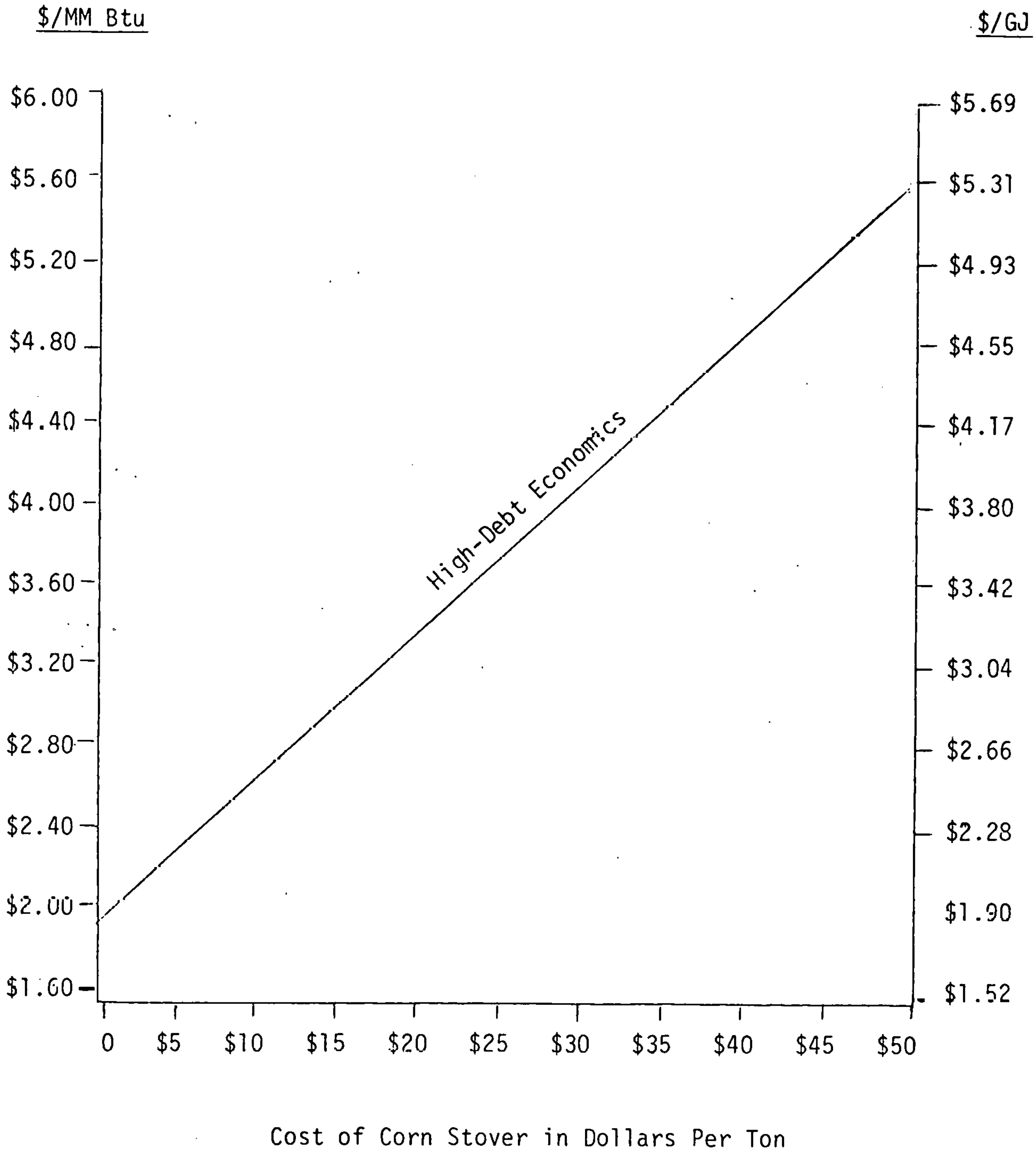
Table 5 compares this process with the Purox process for cost. This comparison is based on furfural residue. The gas cost for dollars per million Btu's is about the same for the two processes.

The Bailie process is a two fludized-bed process. Here is principal advantage is that no oxygen plant is required. Combustion occurs

TABLE IV

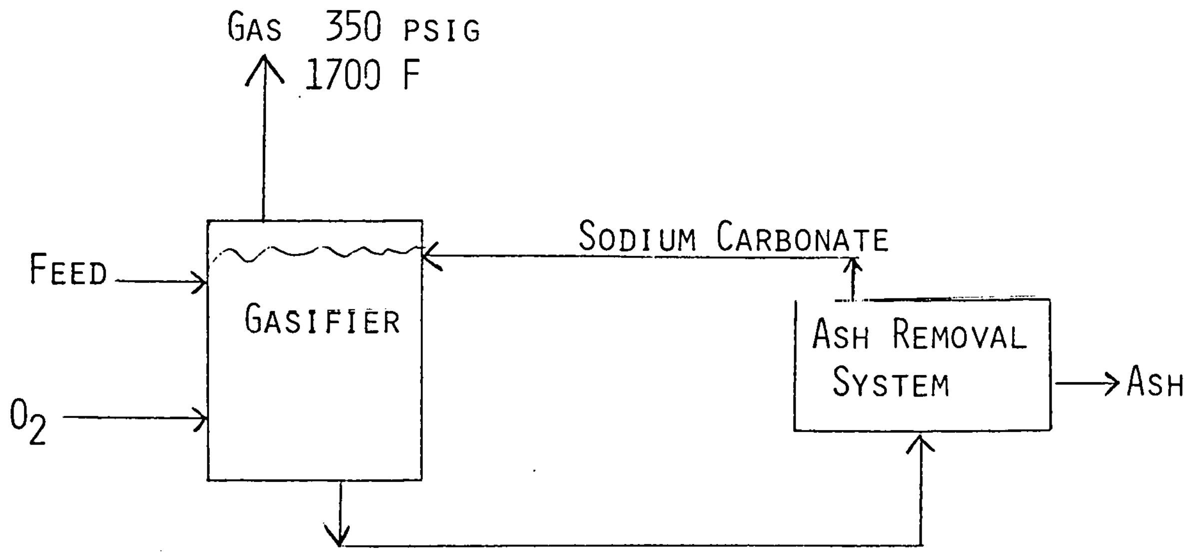
SYNTHESIS GAS MANUFACTURE--PUROX® PROCESS

FEED	STOVER	FURFURAL RESIDUE
AMOUNT--METRIC TONS	2,131	2,866
MOISTURE CONTENT, %	20	35
COST	$40/DRY TON	$1/MM BTU
PRODUCT--MMBTU/DAY	23,350	23,350
TOTAL CAPITAL EMPLOYED	$65,600,000	$60,700,000
ANNUAL COSTS:	MILLIONS OF DOLLARS	
STOVER/RESIDUE	22.50	9.40
OPERATING	7.53	8.13
CAPITAL CHARGE	7.33	5.99
	37.36	23.52
GAS COST:		
$/MM BTU	4.85	3.05



RAW MATERIALS COST AND PRODUCT COST COMPARISON
FOR THE PUROX PROCESS ON CORN STOVER

Figure 3



KELLOGG'S MOLTEN SALT PROCESS

Figure 4

TABLE V

SYNTHESIS GAS MANUFACTURE--MOLTEN SALT PROCESS ON FURFURAL RESIDUE

	Molten Salt	Purox
Feed-metric tons	2,922	2,866
Moisture content	37%	35
Cost	$1/MM BTU	$1/MM BTU
Product	86.8 MMSCF/DAY	23,350 MM BTU/DAY
Annual costs	Millions of Dollars	
Residue	9.22	9.44
Operating	8.05	8.13
Capital charge	6.65	5.99
	28.48	23.52
Gas Cost		
$/MM BTU	3.10	3.05

in one but not the other. More hydrocarbons are formed in this process, which makes conversion to ammonia and methanol more difficult. The Bailie process has been demonstrated at only laboratory scale whereas the others have had more major demonstration than these.

When we turn our attention to the conversion of this synthesis gas to ammonia, we are targeting in on a very large market. Ammonia consumes about 3% of the natural gas that this country is producing. Ammonia is a significant natural gas consumer. Our basis for the cost estimate for producing ammonia was that the feedstock came from a Purox process. Although ammonia is not currently produced from this type of feedstock, we felt that the processes for making ammonia from other materials would be similar to making it from feedstock that came from the Purox process.

Table 6 is an analysis of the cost of manufacturing ammonia. Three cost estimates were prepared. One cost estimate was prepared that assumed that stover from a Purox process was used. Two estimates were prepared on ammonia manufacture furfural residue, one where the furfural residue first went through a Purox process and another one where a molten salt process was first used. The amount of ammonia produced per day in our cost analysis is about 690 short tons.

From Table 6 it can be seen that when we produce ammonia from stover by the Purox process the cost is about $254 per short ton. Last fall ammonia only cost $170 per short ton, so this doesn't appear to be an economical way to produce ammonia. On the other hand, when we compare the estimated cost of about $195 per short ton for ammonia from furfural residue to a projected 1980 price of about $190 to $200 per short ton of ammonia produced from natural gas then making ammonia from furfural residue seems to be a promising venture.

Now let's look at converting stover or furfural to methanol. Methanol has what I call a large market. It consumes about eight-tenths of 1% of our natural gas used in the country. Table 7 shows the cost estimate of producing methanol from stover and furfural that has first gone through the Purox process. An analysis of this table shows that methanol from stover costs $1.09 per gallon and methanol from furfural costs $0.76 per gallon. Neither of these costs compares favorable with the current list price of methanol which is about 45 cents per gallon.

The third conversion process to be reviewed is the conversion of residues and furfural to methane. One of the problems we encounter in this conversion process is that most of our conversion plants must be designed on a small scale. A second drawback from making methane from residues and furfural is that the gas is produced at a low pressure in, say, the Purox process, so more pressure needs to be added to make methane.

There are a couple of things that we can do, though, to make production of methane more economical. There is a chem systems type of technology wherein they have proposed a three-phase methanation or combination methanation/shift catalyst system be used. In this system, the

TABLE VI

AMMONIA MANUFACTURE--690 SHORT TONS/DAY

ANNUAL COSTS	MILLIONS OF DOLLARS	
PUROX PROCESS:	STOVER	FURFURAL RESIDUE
PUROX GAS	37.36	23.52
OPERATING	11.71	11.71
CAPITAL CHARGE	9.10	9.10
	58.17	44.33
MOLTEN SALT PROCESS:		
MOLTEN SALT GAS		23.91
OPERATIONG		11.71
CAPITAL CHARGE		9.10
		44.72
AMMONIA COST--DOLLARS PER METRIC TON		
PUROX PROCESS	281	214
MOLTEN SALT		216
DOLLARS PER SHORT TON		
PUROX PROCESS	254	193
MOLTEN SALT		196

TABLE VII

METHANOL MANUFACTURE VIA PUROX PROCESS--430 TONS/DAY

Annual Costs	Millions of Dollars	
	Stover	Furfural Residues
Purox gas	37.36	23.52
Operating and capital	9.75	9.75
	47.11	33.27
Methanol Cost	Dollars per Gallons	
	1.09	0.76

catalyst was suspended in some liquid such as kerosene for the methanation. Also with chem systems process no recycle is required. This fact enables us to save as much as 25 to 35 cents per million Btu in the production of methane.

A second process that would make the production of methane from residues and furfural more economical is the Syngas Recycling Corporation process. In this process we are using two separate beds for the Syngas preparation in which no oxygen is introduced during the hydrogasification step. It is kind of a two-bed operation like the Bailie process or the CO_2 acceptor process. However, the oxygen is introduced with a char gasification. It is hoped that this process will increase our initial yeild of methane during the first step.

The Syngas Recycling Corporation process has two advantages. The gas ends up to be more pressurized at its effluent pressure and there is a higher initial methane yield. But the cost of the methane gas from this process is $6 per million Btu's. That's pretty high when we are talking about $1.42 at the well head for natural gas.

I would like to make a few comments about the results of our comparison of the cost of using corn stover and furfural with the cost of using bagasse which is the fibrous material left over from a sugarcane extraction. Corn stover basically yields products that cost more than the products from bagasse primarily because of two considerations. One, stover has less lignin content per dry ton, which gives us a lower energy content at the beginning. And two, we have already collected our bagasse at the sugar refinery, so it's delivered at virtually no cost. So we can really talk about $1 per million Btu being a reasonable value for our bagasse.

However, simply because of the way we played the ball game and valued our furfural residue at $1 per million Btu, obviously we will come up with comparable economics for bagasse and furfural. It's implicit in our assumptions. The lignin values and therefore the energy contents are similar on a per ton basis because in the case of furfural we have concentrated the amount of lignin in the stover. The big problem with furfural residue is that we can't put in enough processing plants without overwhelming the market with furfural.

SYSTEM CONSIDERATIONS

E. S. Lipinsky

Battelle Columbus Laboratories

I'm going to talk for a few minutes concerning systems considerations. Essentially what we want to note here is that we do not have a special energy plantation or anything like that that has to be built. Instead, we are talking in this conference about things that farmers can start doing right away if there is a good profit margin involved for them. If one good tree plantation were started now, the first harvest would not be for 6 years. So, the first tangible payoff would be 6 years from planting, whereas farmers could be gathering stover right now if they could find a price for it. Of course, it is going to turn out that there will be competition with food and feed applications for this biomass output. And ultimately, in this country the market mechanism is going to allocate the corn among the various users.

Let's just take a look at a couple of "what if's" here. What if in some year like 1990 or whatever, the United States is using a hundred quads of energy? If we wanted to get 1% of that, that is 1 quadrillion Btu of energy, from corn grain by fermentation, we would essentially have to ferment 4 billion bushels or about two-thirds or three-quarters of the corn grain that we usually produce. Of course, by the time we wanted to make that much ethanol, we might be able to expand our corn acreage to the point where we are talking about half the corn going that way. Still that's a tremendous amount and what it really says is that if we try to think in terms of producing a quad from corn grain, we are thinking too big. We are thinking like a petroleum outfit and not like the scale that one usually works on here.

Let's take a look, though, at the corn stover that's being left out there in the field. If we were to burn up 120 million tons of corn stover, which would be leaving enough on the soil so that not too many environmentalists would kill us, we could get close to 2 quads. But if we used any kind of an energy conversion process that got us a 50% efficiency we would be back down to a quad. So really in order to get 1 or 2 quads from corn, we have to scurry around and pick up almost a hundred percent of the stover that's not needed for the soil, which again is something that really is not all that feasible.

Let's look at it another way. Let's talk about taking 10% of our corn grain and converting that to ethyl alcohol. And basically, this idea looks a lot better because that's more like what we could expect to collect and it would give us about 1% of our motor fuel needs. But, as Dr. Scheller pointed out, this would be concentrated in a few grain producing states and perhaps would be 5% of those grain producing states' needs.

However, using ethyl alcohol will require some very cooperative state legislatures and we don't know how the legislatures are going to look at this type of thing. I think it's better to think of it in terms of the amount of ethanol we produce from corn grain will be roughly six times the current market for industrial ethyl alcohol and we believe that the economic crossover point on industrial ethyl alcohol is virtually here now. So essentially that's the way one could go. And from the chemical industry's point of view, you might say that this type of renewable resource, then, is very likely to be a big success. From ERDA's point of view, making all the ethyl alcohol in the United States is a very samll thing compared to the size of the total crisis.

And incidentally, we believe that petroleum would have to rise an inordinate amount in order for ethylene production from biomass to become a serious possibility right now and that we should not be sitting around thinking about "pie in the sky" on ethylene in the year 2000. We should get to work on the things that work now.

Let's take a look at what we might do with the stover material. Essentially if we make our furfural from stover--and let's not worry about the economics of that at this point, the previous speakers have gone into that--essentially we can get our residues cheaply enough to make a lot of ammonia from the residues. Now, notice I say a lot. In order to produce a lot of ammonia, we are talking about having to expand furfural demand by a very large margin and we will get into the possibilities of doing that in the research and development section.

Figure 1 shows the way our corn is used now and how we might change that use in 2000. Currently in corn grain we are exporting around 30% and one could visualize dropping down on the exports a bit. And, if we didn't use quite as big a percentage of corn grain for animal feed then in the year 2000, perhaps we could be using a fair amount of corn grain for fuels and chemicals. This would be a very fluid situation and it would depend on how much the farmer thinks he can get by selling his grain for various uses.

The corn stover situation is one that I would like to dwell on just for a moment here. Figure 2 shows how we have alotted current and future corn stover use. We have assumed here that there is about a 35% need of the soil for corn stover, that is so that we don't have the erosion. This 35% will be constant. Right now about 10% of corn stover goes into feed, so we have got a lot of stuff lying around in the soil that's really not helping it that much and I'm calling that redundant material. And we can envision that over a period of time if buyers of corn stover such as

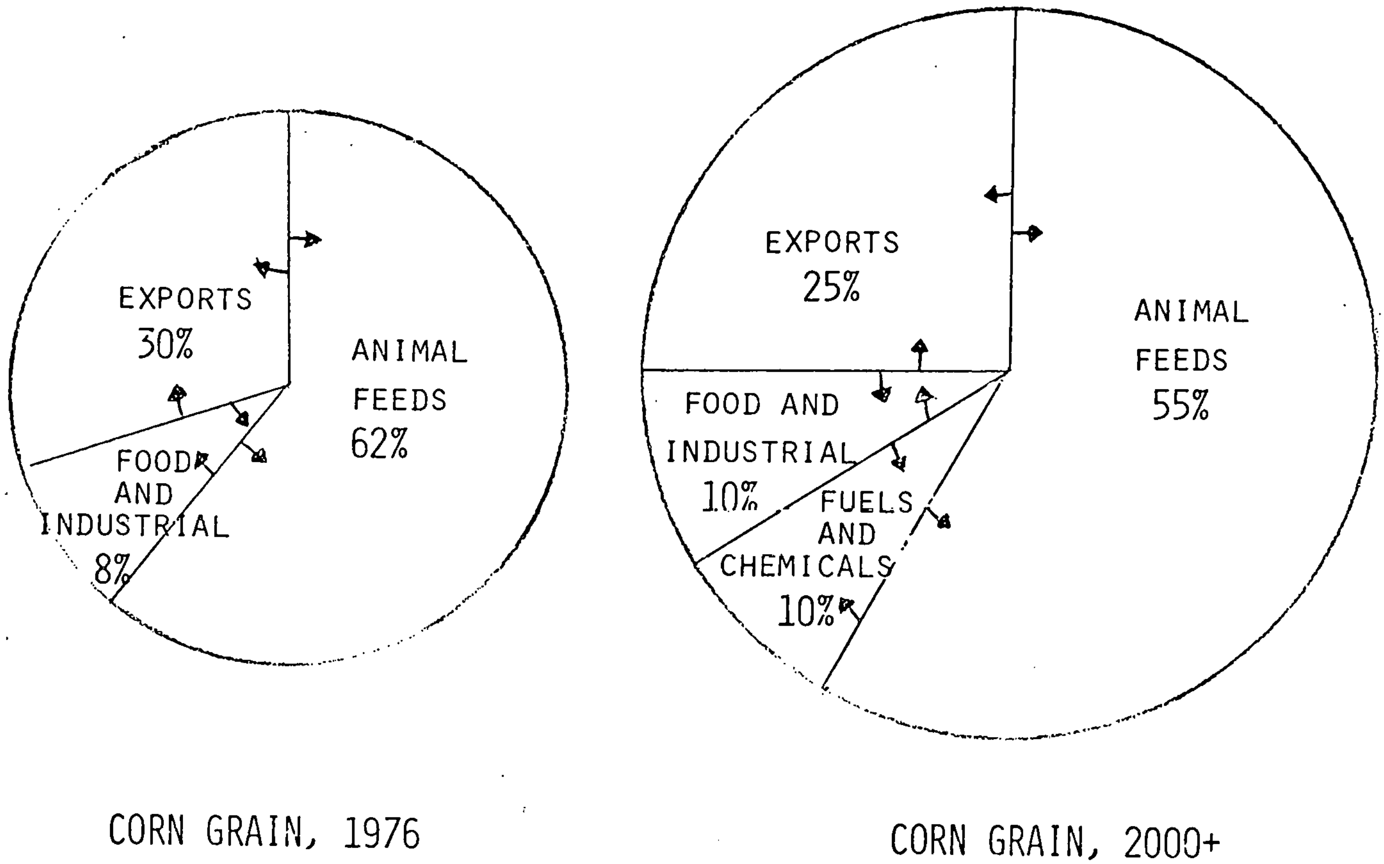
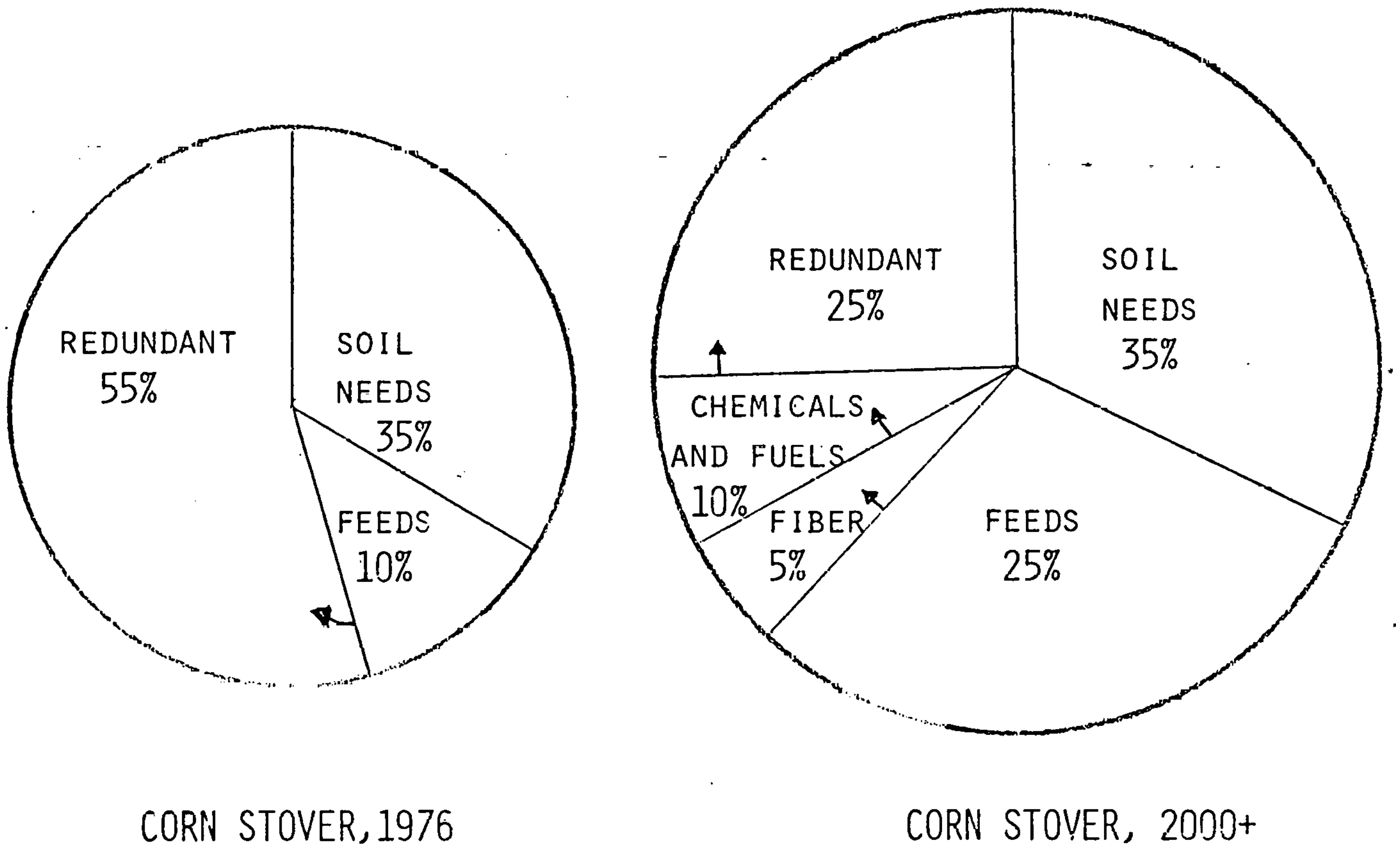

EXPORTS
30%
ANIMAL
FEEDS
62%
FOOD
AND
INDUSTRIAL
8%
CORN GRAIN, 1976
EXPORTS
25%
ANIMAL
FEEDS
55%
FOOD AND
INDUSTRIAL
10%
FUELS
AND
CHEMICALS
10%
CORN GRAIN, 2000+

Figure 1



REDUNDANT
55%
SOIL
NEEDS
35%
FEEDS
10%
CORN STOVER, 1976
REDUNDANT
25%
SOIL
NEEDS
35%
CHEMICALS
AND FUELS
10%
FIBER
5%
FEEDS
25%
CORN STOVER, 2000+

Figure 2

Quaker Oats and The Andersons and others were joined by additional buyers then one could get to the point where both the feed use and the chemicals and fuels use of corn stover expand.

The farmer has got to decide what to do with his corn stover, whether to feed it to his cattle, put it on his soil or sell it to somebody else, and he's got one of the sharpest pencils in the country as to how that will work. Once the stover gets to the processor, that processor has to decide whether the price of fuels is high enough so that he will be in the fuel business or whether he would rather stay in feeds or chemicals or whatever. The same sort of considerations apply to grain. A diagram of these decision processes is in Figure 3.

So here we have a situation in which we are looking at an interesting opportunity for the farmer. The farmer who sells his corn stover for making furfural or ammonia or whatever is also a big buyer of fertilizer and feeds. If he's making a deal in his local community where he can be assured of getting urea for feeding use and fertilizer for corn planting in exchange for selling his corn stover, then the whole process begins to have a very good fuels and chemicals systems feel to it. There is a motivation for the farmer to price his thing he's selling at a reasonable price and there's a motive for the man processing the stover to be equally reasonable because he's got a plant that he can't move away from that area. He's got to deal with that farmer year after year.

In the corn grain situation, one could be making ethanol primarily for chemicals use. Essentially we are saying that the ethylene and major polymers use is a long term future deal.

So the conclusion that we come to in this systems considerations is that the corn all by itself is certainly not going to solve any great big energy problem such as the United States has. It does have some essential roles to play, especially since this sort of toll ammonia system may represent a very nice bridge that will get the farmer accustomed to selling to a chemical manufacturer instead of to his traditional markets. The corn, of course, is going to have to fight it out with sugarcane for ethanol markets and, or course, Battelle is on both sides of that fence. We reported last fall on sugarcane, and sugarcane is a lot less optimized as a system than is corn. We can see some ways in which the yields of sugar and the cost of sugar as raw sugarcane juice in the United States can be brought down a lot. However, we have not found comparable cost efficiencies of future things to be done with corn, simply because the corn people have done such a splendid job up to now. However, we think that corn will have some success but that's going to await research.

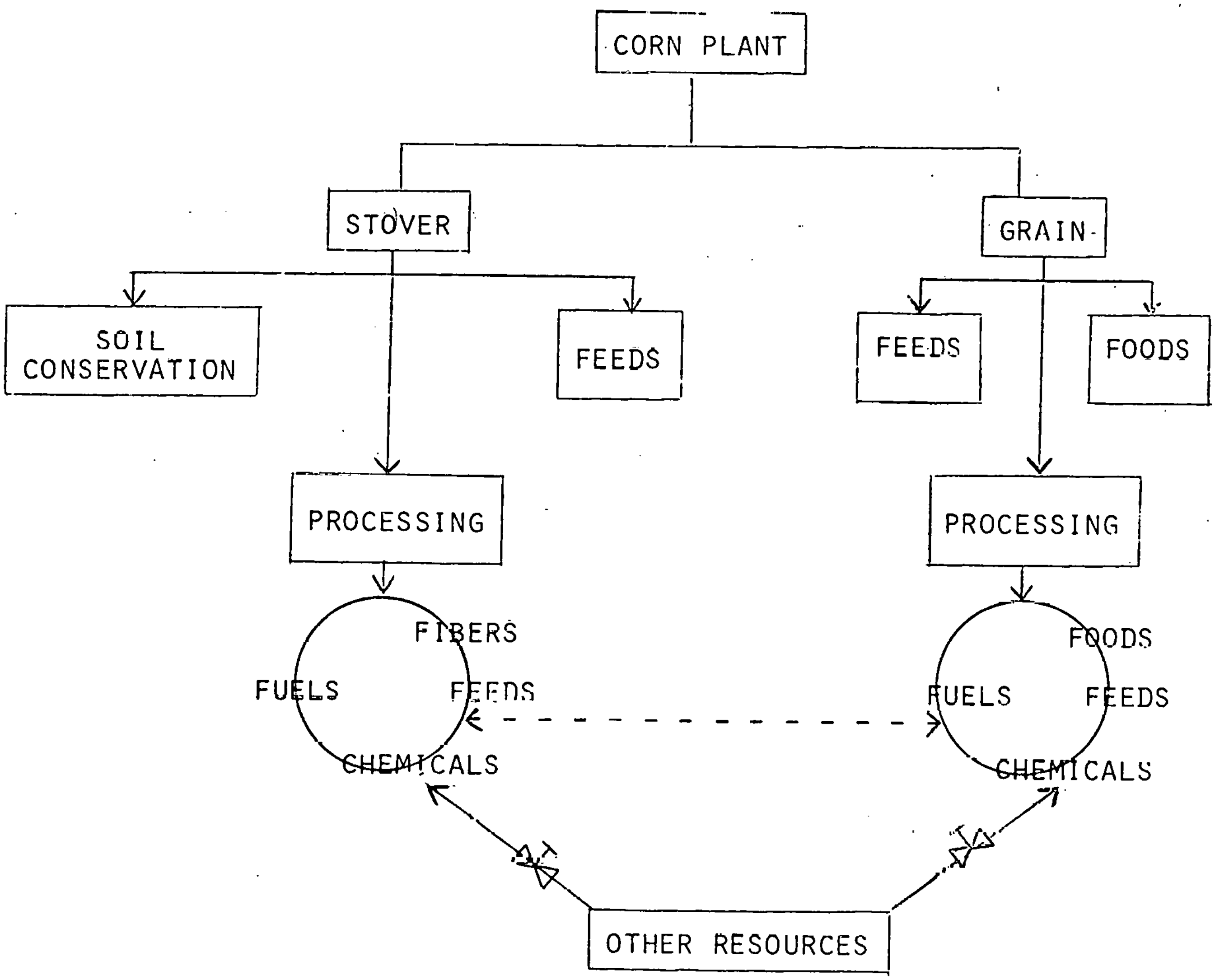

CORN PLANT
STOVER
GRAIN
SOIL CONSERVATION
FEEDS
FEEDS
FOODS
PROCESSING
PROCESSING
FIBERS
FUELS
FEEDS
CHEMICALS
FOODS
FUELS
FEEDS
CHEMICALS
OTHER RESOURCES

Figure 3

RESEARCH AND DEVELOPMENT OPPORTUNITIES

E. S. Lipinsky

Battelle Columbus Laboratories

Now we come to the research and development opportunities. Remember that corn is not identical in its composition to things like coal or petroleum. It's wet compared to petroleum and coal, it's got a different carbon content, it's more reactive, it's different. The corn residues we feel are greatly underutilized. These residues have got a lot of polysaccharides and not much lignin which suggests something. Mainly, that this is a lot better material to try to hydrolyze than is wood. We feel that the people who are looking at trees for hydrolysis are looking at the wrong raw material. Corn residue would be nice for hydrolysis.

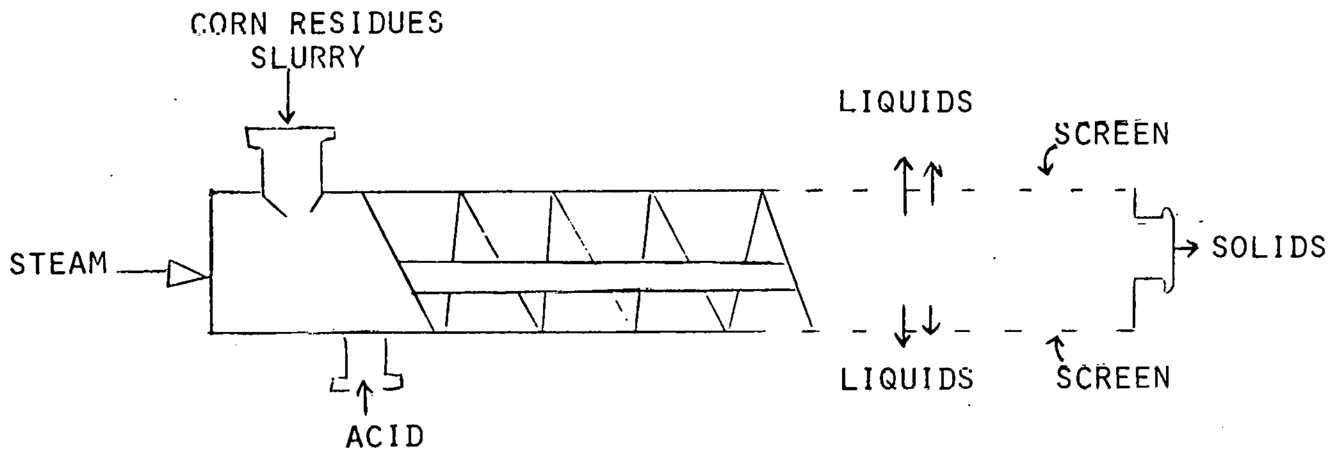
However, we do know from Professor Wilke's experiments and others that enzymes are slow and they are costly, so that's a long range situation that we should not stop working on, but we just shouldn't expect any big commercial results soon.

Where can we get some commercial results sooner? One thing would be to do one of these acid hydrolyses. The trouble with acid hydrolysis is that people have tended to act like a broken record. They used the same dilute, strong acids decade after decade starting in the 1900's, sulfuric acid, hydrochloric acid, and you get processes that are terrible to control. And the reason goes back to some basic physical, organic chemistry, which is that when you make the sugars from the polysaccharides, the sugars are more readily clobbered by acid than are the polysaccharides in something like corn stover. So you get a mess.

Now, there were some processes with strong acid, but those need a magic recovery system, which nobody has invented. So let's see if there is a way out of this.

Well, surprisingly, the weak acids like acetic acid have been looked at very little. There is a nice interesting patent by a man named Snyder in the late fifties and virtually no other work on acetic acid. So by using a weak acid in a buffered solution one can get a situation where the polysaccharides tend to hydrolyze well, but the acid isn't sufficiently strong to do these dehydrations.

Figure 1 suggests a method for hydrolysis using a screw conveyor. In this process, you would take the corn residues, the stover and slurry and push them through a screw conveyor with steam to get your temperature up. When you have got that stuff hot, you put in one of those weak



SUGGESTED HYDROLYSIS PROCESS USING SCREW CONVEYER

Figure 1

acids like a citric acid or acetic acid and run it through for the appropriate length of time. At the end of the heating with the acid, you squeeze the liquid out of the material. And one could hope by controlling the conditions to end up with a very fast reaction, but a very gentle reaction for hydrolyzing corn and stover. We think that's what ought to be looked into.

The benefits we could expect would be that you would be upgrading your stover. You no longer have to worry so much about whether it's $25 or $36 per ton if what you are doing is making sugars out of it. However, I should point out right away that as soon as we have got those hydrolyzed sugars there, we have got something that competes with molasses that's worth $80 a ton and we may find that the durned cattle and other animals start to eat the stuff up. But it does give us a pretty good chance on getting some chemicals like ethanol more inexpensively. We do have some other drawbacks here in that, as well as the simple sugars, we get a bunch of sugars that don't ferment to ethyl alcohol all that well and we do get some disacchrides.

Well, without going into all of the research needs in detail here, some of the areas that would need to be investigated are: (1) which acid would we use (2) which buffer (3) what concentration of the acid would we use (4) what temperature would the process proceed at and (5) for what amont of time (6) what would be the concentration of our feedstock, and (7) what parts of the corn stover would we use (8) how fermentable would our end product be and (9) how edible as an animal feed? You can see that an extensive amount of research is still required.

Another area that we feel deserves some research and development is producing synthetic natural gas by anaerobic fermentation of corn residues. It would provide a moderate level of energy production, but would possibly be quite low in cost. We have already said that stover is low in lignin and everybody who tries to do anaerobic digestions keeps complaining about lignin. So surely we should be able to succeed in making synthetic natural gas from corn residues and that was what I thought when we first wrote one of our draft reports.

But when we looked into it, we found that some of this work has been undertaken by Buswell, who is the best of the anaerobic digesters. But he could only get about 30% of the theoretical yield of synthetic natural gas from cornstalks in 15 days and he left fermentations or anaerobic digestions go for 100 days without them being complete.

But one of the key things that Buswell did not properly look at was the particle size of the corn residue. That is, we have a whole great big monograph of his, and he worked a great deal with shredded products but not with fine particle sizes, and so he was probably encountering a diffusion problem.

Now, we were pleased to find recently that the University of Missouri has looked back into this area, but they still get only about a half of the product consumed or maybe somewhat more than half in 40 days. So there are some funny things going on in here and it may be simply diffusion or it may be some strange pentose, metabolism or whatever.

But at any rate, what we decided was that if nature wants to leave these fibers intact let's not argue with her too much. Figure 2 shows a suggested digestion process. The idea would be to bring the residue into an anaerobic digester and count on the fact that it's the fine particles of this material and not the good fibers that are going to ferment first. So we make this a separations deal that may go around and about several times where we are digesting the less suitable fibrous materials over into SNG and carbon dioxide and what's left we hope will be the more resistant cellulostic fibers that can then be used for paper making pulp. The undigested corn fibers do have bad length to diameter ratios. We would be fermenting the corn fibers that are sticky and by being able to sell our cornstalk pulp, we would hope to wind up with a substitute natural gas product that's relatively economical.

So, of course, one needs to worry about the synthetic natural gas yield, its composition, what's the pulp yield and what's its quality. The usual nutrient sources are from sewage and manure sources and that's not very good news if you are planning to make fine grades of writing paper out of this. Certainly you couldn't make food board out of this. So there are some questions that need to be answered by research.

Let's turn our attention for a few moments to furfural. We feel that in order to get our ammonia nice and cheaply we have to do something with furfural. It's a very well understood product. There have been thousands of papers on it. It's really a question of getting the cost down and assuring a reliable supply. There are many uses for furfural at which the current price is favorable. These uses include nylon, tetrahydrofuran, phenolic resin and maleic anhydride. In these four areas, there is a billion or so pounds of market potential to go after. But essentially what one has to do is to get the cost down. One possible way to lower the cost is by a good acetic acid recovery so that you get more dollars from each ton.

We could also make furfural by beginning with the process that we showed with the screw conveyor. As shown in Figure 3, we could get the xylose and other five carbon sugars out of a lot of this raw materials first. By using the screw press we could hope to make a separation, get the pentoses cheaper, get the furfural faster and purer and from the xylose and five carbon sugars get ethyl alcohol as the co-product.

And, of course, once one has that furfural residue, one can then use this residue to make ammonia or methanol or, probably less likely, thermochemical synthetic natural gas.

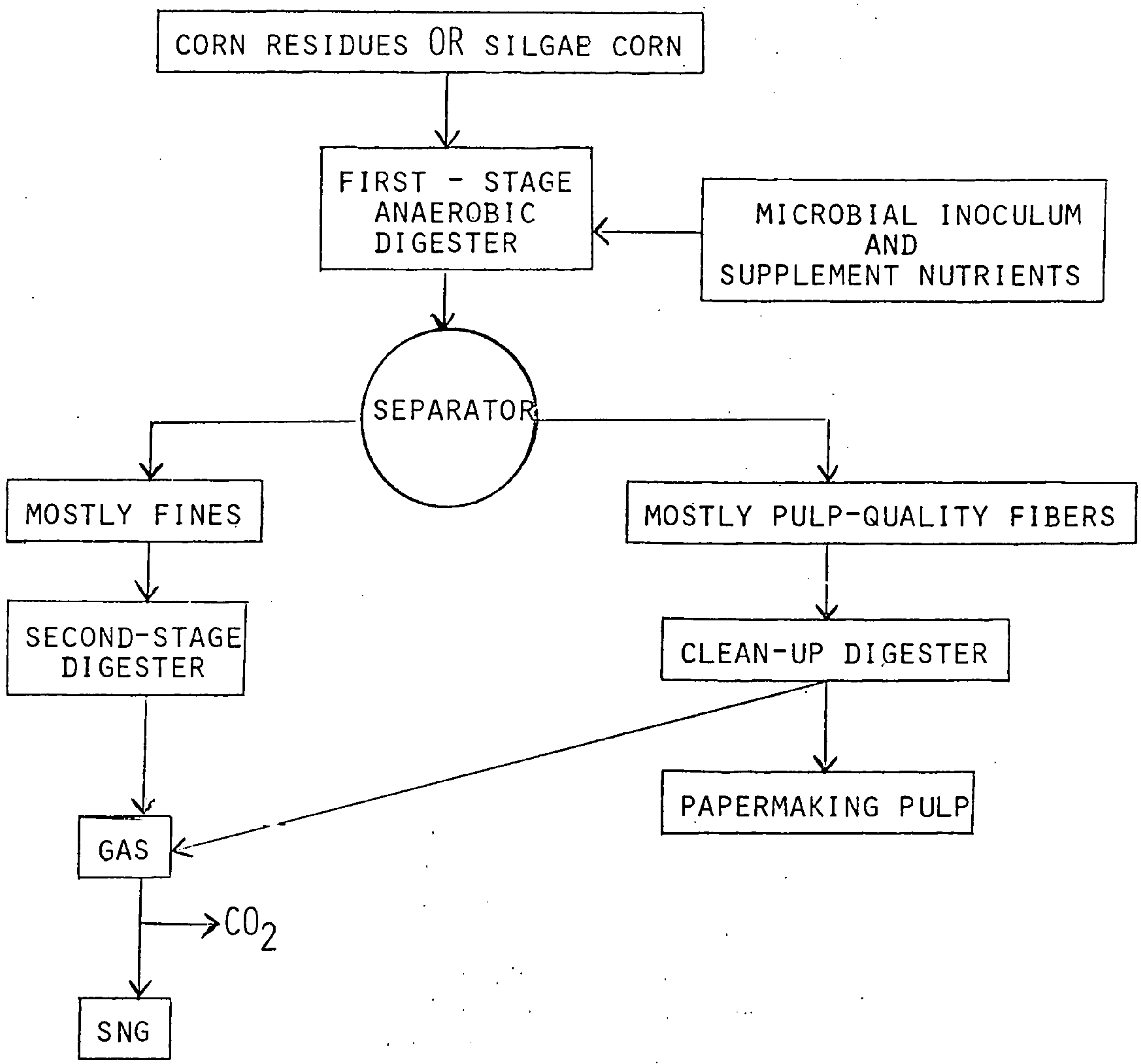


Figure 2

SUGGESTED PROCESS TO MANUFACTURE SNG AND PULP

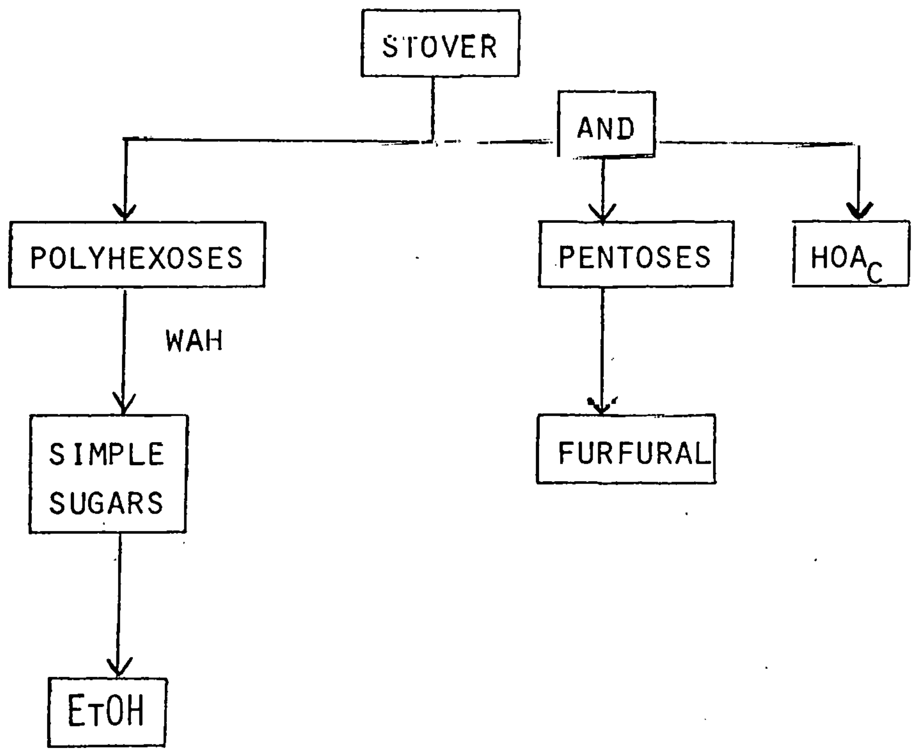

STOVER
AND
POLYHEXOSES
PENTOSES
HOA_C
WAH
SIMPLE SUGARS
FURFURAL
EtOH

Figure 3

I would also like to mention the alcohol fuel situation where great progress is being made in Brazil and, as we can see, a lot of experience is being gained in Nebraska, too. Our own suggestion in this is that it would be very good to run what we call double blind experiments where neither the experimenter nor the driver knows when he's using gasohol and when he's using the control material. The reason this is important is that there has been a lot of controversy on this and this is the way to document the 5 or 6% mileage increase if that's what really applies. That's also the way to keep the members of the American Petroleum Institute and some of the automobile companies from having their drivers tromp on the accelerator a few extra times at every stop light, thus showing that the mileage decreases instead of increases. So for years we have done work on various additives to coffee and we have always found that it's necessary to run double blind experiments. Otherwise, the experimenter tips off the user as to what he should be doing or else the user gets mad at the experimenter and fouls up the experiment on purpose. So this is our suggestion, that ERDA should consider very strongly supporting some double blind experiments to document the mileage change, be it plus or minus.

Now, so far as agricultural research and development is concerned, if we were going to go after this substitute natural gas and fiber market, it would certainly be desirable to grow a special silage corn for this. So it would be possible to tailor corn genetically for these particular qualities. I don't think I will mention high oil corn here except to mention that if we had a corn with 18% oil at a reasonable cost, the food industry is going to grab it away from us before we can use it for fuels anyway.

In summary, I would like to say that corn as an energy crop does have some modest prospects and we should neither count on it to save us nor should we write it off and start looking for things like giant reeds or other weird plants. It has its role to play. It's going to require, we think, some research before it can play that role adequately. We do believe that nonfuel markets are going to have a lot of impact on the fuel prospects. And essentially that the ultimate bottleneck is the cost of the corn stover. That cost has a large psychological component to it. If the man expects to collect for his corn stover that he sells to the chemical company the same amount of value that he has in livestock production, then he's not going to sell it at all. He's going to stand there and watch it rot.

We do feel that there are a lot of crops that are useful and although this one has been close to optimized, agronomists of the world should arise and unite to find crops that have the favorable characteristics of corn without some of its drawbacks.

DR. BENJAMIN J. LUBEROFF, EDITOR

CHEMICAL TECHNOLOGY

I really don't know what I'm doing up here. I couldn't believe that Ed Lipinsky would invite a New Jersey boy to Kansas to tell you about corn. The only thing we know in New Jersey about corn is that if you don't eat it 30 seconds after it's picked you may as well let it rot and drink it.

So I sort of came to the conclusion that Ed had in mind that I talk about something else. I was afraid to ask him what he wanted me to talk about for fear he would say talk about an hour and that would consume more time than everything I know. So let's see if we can stay together for maybe a half an hour. My job will be to talk; yours is to listen. If you finish your job before I finish mine, just raise your hand.

Let me tall you what I have been hearing today in the form of a little story. It seems this lady showed up at a dry goods store, emporium, and she asked for 25 yards of peach colored chiffon. The young clerk said, "Yes, Miss. May I ask you what it's for?" She said, "Oh, yes. I want to make a nightgown." She said, "One?" The lady said, "Yes, just one. You see, I'm marrying a scientist and this is for my trousseau. You know how scientists are. They get a lot more fun looking for it than they do finding it, because when they find it they don't know what to do with it."

I'm hearing some of that today. I'm hearing about some of the fun and games of counting corn cobs and doing a lot of interesting computations, speculating a lot. What I'm not hearing and what worries me, and frightens me, is I'm not hearing about out addressing the big problem, the energy problem. That's the name of the game. The name of the game is let's solve the energy problem. It's not let's sell corn, it's not let's get grants, it's not let's keep our jobs at the universities. What I would like to address your attention to is this vast concept of our energy problem and I preface this by saying you don't start vast projects with half vast ideas.

I put this sort of thing to Betsy Andrew Johnson not long ago at an American Chemical Society meeting. She had gotten up and she was decrying the fact that the productivity of Americans was growing at a slower rate than the productivity of the Japanese, Germans, French, and that this really was the justification for our doing more research. And I rose and I pointed out to Dr. Andrew Johnson that it really didn't concern me very much that my 6-year-old was growing at a faster rate that I was. She said, "You mean to say Japan is an underdeveloped country?" Well, in certain cases they are. And I went on to ask her what she thought the research expenditure of the government was going to be to do something about all this. I said, "What do you think would happen if the federal government stopped spending money on research altogether?" And this really rocked her and her answer was, "Why, do you know how many professors there would be without jobs?" Then she realized that didn't sound so good. She said, "The American public would never stand still for our stopping research on transportation." At this point she thought better of saying anything else and didn't.

The point is we are not running a make-work project for professors and nonprofit organizations. We are not just producing numbers. Hopefully we are solving a problem. You know what the problem is.

The most recent comment I heard on it was former Ambassador Nolte, ambassador to Egypt from the United States, who said, "By 1980 the U.S. will import half of its oil and half of that is going to come from the Saudis." He went on to point out that the Saudis already have a surplus of $53 billion. Now, what could they buy in the United States with $53 billion, which represents something more than 10% of the annual federal budget? And that, ladies and gentlemen, scares the daylights out of me. If this country is supposed to continue being independent, it's going to have to be independent.

So I would like to share with you some thoughts as to how we might approach that and there may be very little corn in the argument, for which I apologize. It really isn't fair, having had my lunch bought for me, to criticize my hosts, but I fear as a professional I have to tell my client what needs to know whether my clients wants to know it or not.

We heard something the other day about the possible solution to this, mentioned by Mr. Kimball, underlined by Mr. Sosland, that perhaps the thing to do would be to forget the energy business altogether because food comes before energy and human needs. So we will become the breadbasket of the world and in that position we will then control our source of energy by controlling the food supply. Well, I don't like that. I don't like that because we are forcing on other people what we don't want forced upon us and there is an old law that says that you don't do that.

So I think we have got to solve our own energy problem and like the solving of any problem, I think really what we have got to try to do it bring together a thing called a market, a need, and a thing over here called a resource. We have to bring them together so that the resource fills the need. This is different from a waste disposal problem where I have a resource I'm trying to get rid of. Market; need.

The market I think we are pretty clear on. The market is let's make energy. And I don't care how we make it. I don't care whether we make it from corn or cabbages or rooftops or red pines or rutabagas. I understand there are some guys even trying to make energy out of cow manure and that, incidentally, is an interesting switch. Probably one of the earliest advocates of solar energy as a technology was J. Farrington Daniels out of the University of Wisconsin, who is a physical chemist. About the only people who would listen to him were some do-gooders at the United Nations. These people at the U.N. were worried about the fact that the Indian housewife in India was burning cow dung instead of plowing it back into the fields and their fields weren't fertile. We had to give the Indian housewife an alternative to burning the dung of cattle and that alternative, obviously, was a solar cooker. The U.N. spent a good deal of time and came up with a very nice sophisticated little solar cooker. Except the Indian housewife was having none of it.

A lot of people seemed to think that this was because the India housewife was not about to take the second best. If she was going to have a stove, it was going to be a GE electric with a self-cleaning oven. But it turns out that really wasn't what was involved. What was involved was a failure of us to recognize the characteristics of the market. When you are in a hot country and you work very hard and it comes time for dinner, you generally have dinner after the sun has cone down and the solar cooker isn't much good.

Now, I mention this little allegorical thing of going from cow manure to solar energy back to cow manure to show you that the more things change the more they remain the same, but also to call your attention to this business of understanding your market.

I was much impressed with the work being done by The Andersons. They are not selling corn cobs. They are serving markets. And I would be willing to bet that probably one of the highest cost items in their budget is a thing called "tech service."

So we have got that market out there. And now we have got this resource and the resource I have reference to, of course, is the sun. Now, there is nothing new about the sun. I call to your attention the fact that every bit of energy, with just some minor exceptions, produced and used on the face of this particular planet, up until Alamogordo, came from the sun. Petroleum is solar energy, coal is solar energy, natural gas is solar energy. It happens to be fixed energy, it happens to be our capital, the big bank account in the ground that was the legacy we inherited. It took a long time for the earth to acquire that capital and we have blown it very rapidly. There ain't going to be no more. It takes too long to produce. And anybody that thinks very hard knows about the hazard of living off of capital and yet we have been doing it. We have been doing it for a long time.

Well, the salvation, of course, was supposed to be nuclear power, but it turns out that that bank accounts limited too, because that's capital. There is only so much uranium in recoverable form. It's a temporary fix and it's got some negative aspects to it. I'm not about to assume responsibility for leaving a legacy around for 25,000 years that God didn't see fit to put here and I am making reference to plutonium, of course,

So what I think we have got to do is address ourselves to the big problem. Energy, for those of you that have forgotten, is the ability to do work and when we lose that we have lost everything. And the place you are going to find energy is current income from the sun.

Incidentally, you have all heard about the boys that are going in the fusion business, the fusion reactor. Their problem, of course, is that they have a problem of containment. They can't find a pot to hold this thing in because it's too hot. And so much of the current thinking now has to do with creation of a weightless environment, which would deal with a lot of magnetic fields and so forth, which would consume ever so slightly more energy than it produced. Or else there is the other idea to set the thing up and shoot it out into space, and you will now have this fusion reactor out in space.

We might just as well call it the sun because that is what it is. We have got a fusion reactor out there. It has got a wonderful launch stream record, hasn't had any labor problems lately, doesn't corrode, and we don't have to write an environmental impact statement about it.

So let's agree that our market is the ability to do work, energy, and our resource is the sun and our job is to try to bring these two things together. This is nothing new. This is the way technology is always used.

What's technology? Well, some of you out there may remember having seen a thing that used to be called a corset. It looked something like shoes that used to lace and those of you that don't remember corsets and shoes maybe can think about what a football looks like. But what you have got are two halves of this thing that are trying to pull each other apart and you are putting a lace back and forth, back and forth, between the market and the resource, to pull them back together again. Okay. That lace is technology. There is a little bit of science involved in the lace. There are a lot of other kinds of things involved in the lace that are necessary to pull this thing together around this real fat lady. And this real fat lady, of course, is society, who is exerting a resistance to our bringing together the resource and market.

And so what I would like to suggest we do is possibly look to see how we are going to pull this thing together. I think you can see the fallacy of trying to lace up a corset if you only put the laces through the one side, that is to say if all you do is look at the corn. I think you can also see the fallacy of trying to put the resource and the market together if your lace is made out of nothing but some good ideas and some good intentions.

So we have got sun and around here I guess we measure that in terms of land area, that's the collector for the sun. Some people have talked about putting a satellite out in space, a synchronous satellite to collect the sunshine, convert it to microwaves and beam that back. I point out that takes a fair amount of land too, because you need an antenna to collect those microwaves and if the thing gets a little bit out of sync, you can fry a whole town. So you have got to have a pretty big land area even for a solar satellite.

So we are really talking about a resource called land, which to farmers is nothing new. As a matter of fact, I think it's a very interesting concept and if I'm intriguing any of you to want to pursue any of this further, you would be interested in hearing about Henry George. Many people call him the first American economist. Henry George began enunciating some concepts of economics just a hundred years ago immediately following the great depression of 1873-78. And at this time we were also looking at the land again. And George made the point that economics is the allocation of scarce resources. You use the land that's most accessible, the land that will do the thing you want it to do first and when you have run out of that land you use other land.

And right here I would like to just stop and comment on what the press has done about this conference. Those of you that haven't seen it, it's in this morning's Kansas City paper. Basically what the press heard and now what the public hears is that there is a head-on conflict between the production of food and the production of energy. I'm afraid there was some of that coming through yesterday. But Georgian economics says that doesn't necessarily have to be true. I quote from one of our speakers this morning. The characteristics of land to grow corn, level, gently rolling, medium texture, favorable temperatures, adequate rainfall, high moisture holding capacity. That's not marginal land. That's like it says on the back of every one of the seed packages that I buy. They all want me to have good, fertile, well drained land. I haven't got any of that stuff, that's why I am growing flowers.

But you can grow trees on slopes, you can grow reeds in land that even a Florida real estate developer couldn't sell because it's under that much water, you can grow things where the soil is pretty dry. I understand mesquite is an epidemic in part of the country and you can burn that, you can digest that. So we are not necessarily saying we are going to have to take this land out of production any more than we say you are going to have to chase the cattle off because we want to graze the sheep or you can't put your cornfield here because we are going to put up a real estate development. I mean this is not a new thing. This is an orderly progression of the economics of the United States and it's just a matter of our allocating our resources.

If you want to know more about Henry George, even though it's a hundred years old, there's a Henry George School and a Henry George Institute in New York. The Henry George Institute will for free carry on a correspondence course with you based on Henry George's writing and it's a lot of fun. All you do is write to Henry George Institute in New York and tell them you would like to participate and they will sell you the book for about $8 and you have a correspondence course. If you are in New York you can drop in at the Henry George School and take a quick short course in economics. It's simple. Even I can understand it.

At any rate, that's our resource, that's our market. Let's look a little bit at our technology.

Well, we recognize that we can convert solids to gases and gases to liquids and we recognize that sometimes you want a gas and sometimes you want a solid. See, the reason that we are converting coal to gas is not because we don't know how to burn coal. But why are we converting coal to gas? We destroyed our railroads. We have no way to haul the coal around except to pump it in a pipeline that already exists. These are technological concepts. These are the things that tend to pull the resource and the need together.

Let's talk a little bit about the restrainst, the fat lady that we are trying to put into this corset. Well, we have that wonderful group of things called thermodynamics. When I used to interview kids for jobs I would always ask them, "What did you learn in thermodynamics?" And they would list all of the Maxwellian equations and all the good integration stuff they had learned and stuff. And I would say, "But what did you really learn?" The ones I hired were the ones who said thermodynamics tells you what is possible.

That's really what it's all about, what is possible. And we have got to live with that. We have got to live with the fact that heat does not flow from a cold body to a hot body. We have got to live with the fact that every time we undertake an energy transformation something is lost and gone forever. We have got to live with the fact that nature tends to a state of maximum confusion, which is entropy. We have got to learn to live with the fact that if we want to really boil the daylights out of something with a real hot flame under a pot of water at 100°, we are going to be wasting a lot more stuff than if we warm it up slowly, use a small temperature differential, use a great big heat exchanger and a small temperature drop. If we do things slowly, the loss of energy is least. But who can afford to pay for the big heat exchanger? The same jokers that blew the capital that was in the ground, now we have got to put some of that capital back, we have got to invest to make up for what we have blown in the past.

There is another group of restraints. I call them psycho-social restraints. They are the things that make us do such intelligent things as set our air conditioner in the summer at 65 and raise 14 kinds of hell when Mr. Carter says in the wintertime set your thermostat at 65 because we would rather have it at 80. But when the temperature outside is at 80 it is too hot; that's why we set our thermostats at 65. It's why we drag around a ton and a half of steel to take a 100-lb girl to the supermarket where she looks for dietetic food because she's not getting any exercise and when she gets home and puts the car in the garage she puts on her jogging suit and she does jogging, but Lord help her if she tried to walk to the supermarket and back.

We have these wonderful houses that we built lately. Remember the way we used to build the houses back in the days when we wanted to keep the environment out? They had thick walls and little narrow windows. Now we have got thin walls and large windows and we bring the outdoors in and put the swimming pool in the living room and then wonder why it's costing so much to heat the darned thing.

What do we insulate our great big high rise building with? Sheets of glass. That's bright, isn't it? Look at the way they insulated a cathedral. Did you ever notice radiators in a cathedral? An air conditioning system? You probably never went into a cathedral that was too hot or too cold. We have changed our way of thinking. New we want the outside inside instead of the outside outside where it belongs.

All that's got to be changed. This lady has got to go on a diet or we are never going to get the resource back to the market.

Now let's go back again. See, this is the way it works and this is one of the points I'm trying to illustrate. It's a back and forth, back and forth. You look at the resistance, you look at the market, you look at the resource, you look at the resistance, back and forth, just like a lace.

Okay, let's look at that market. Why are we trying to make alcohol out of corn cobs? Well, because you can't pour corn cobs into a farmer's tractor. Okay. And the tractor is a big energy consumer. Well, what does the tractor do? Well, a tractor imparts energy to the soil. I mean that's really all a tractor does, takes energy out of the alcohol or the diesel fuel and puts it in the soil. Is there a better way to put energy into the soil? I mean if you insist on growing corn you are going to have to do such things as plow and cultivate and harrow and whatever the other words are that I don't understand, but if you grow trees on a rocky slope you couldn't plow it if you had to. If you grow a perennial crop you don't have to do quite so much of that. This is the understanding of the market, the solar stove that you use at night.

There are other interesting things like that that could bear closer examination. If you put this stuff on the back of a truck and took it down the road at 60 miles an hour it would blow all over the road, so how in the world are you going to get it from here to there? And how are you going to get it dry? Well, the old law, if you can't beat 'em join 'em. I wonder if anybody has thought yet about the idea of a slurry pipeline to carry corn stover or wheat straw? Slurry pipeline. They are using it for coal, they are using it for ore. The stuff is pretty wet to begin with so you can't make it any wetter and when you get it where you want to you dry it then. Yes, but the stuff might rot because it's lying in that long pipeline for hours and hours. Well, now, there is an interesting thought. If it rots and it's anaerobic, we may put corn in one end of the pipeline and out of the other end will come you know what. This is an understanding of the market. It's the tying together of the market and the technology.

And it's the thing that just can't take a monomanical view. I'm a corn farmer and that's all I want to know about, my father was a corn farmer before me. Or I am a physical chemist and we don't get our hands dirty with things that are organic. I used to be in the egg business with Stauffer Chemical and I went out one day with some of the fieldmen to see how it was really done in the market because I was a research type. The farms in this particular area were beautiful except for one. I mean it was sad. Everything about it was sad. And we drove into this farm and said, "We have come from Stauffer Chemical Company," That's all we had to say. "Don't use any chemicals; an organic farm." We said, "Well, that explains a lot. Is there any way we can help you?" "Don't need any help." "Well, okay. We tried. If ever we can help, we will leave a card with you." Got back in the car. He looked at the card. He said, "What kind of chemicals do you fellows sell?" And I got the bright idea of saying, "We sell organic chemicals, sir." "Well, come in and sit down, son."

Too often it's what we call ourselves. It's how we see ourselves. I think it's important to remember that really what we are trying to do is put the whole lady inside of the whole corset.

What kind of technology are we going to need? Well, how do you plant on a slope? How do you plant under water? How do you use the whole plant? Has anybody really tried to breed a plant for its energy content, total energy content? I don't think so. I mean I'm no agronomist but I have talked to a lot and they say, well, yes, but really not yes. And I'm talking about available energy. That means available energy after you get done doing all the things you have got to do to it, like chop it and dry it and pelletize it. And incidentally, when you are pelletizing that stuff, if you squeeze it together enough you will never get it to react with anything. Keep that in mind. That's the big problem I understand they are having against hydrolysis up in Navy town. They can't get the stuff inside where it's going to do some good.

Are we really cropping in the way we should? I mean everybody knows how to crop corn if they want to get kernel corn or ear corn. But do we know how to crop trees for their energy content? Do we know which varieties to use? Do we know how much water they need? We don't. That's what technology is about.

One of the things, incidentally, I would like to caution you on in developing your technology, something I have seen here repeatedly, if there is anything people in the chemical industry want to avoid like a plague it's a two-product plan. Phenol and acetone is a good example. Butanol and acetone is another example. You never know how to price anything. For example, we saw some very interesting pricing information here where right at the beginning it was assumed that the byproduct was the feed that's left over and so you subtract that from the cost. But supposing the market gets a little out of kilter and that's the thing you can't sell. Just learning how to keep the books gets to be a real problem. And the fact that you are serving two markets with two different marketing organizations is a real problems.

On the other hand, it's not impossible, because if you ever want to see anything weird it's the bookkeeping that goes on in an oil refinery where you have got one barrel of stuff coming in and 79 different kinds of barrels going out and every day that mix of barrels changes and the market changes. So be forewarned, it's that kind of a ball game.

Another thing I have heard a good deal about is a pilot plant and a demonstration plant. It has been my experience that pilot plants are excellent for creating and solving problems that occur only in pilot plants. When you have got an emergency like we have now, go take the risk of building a bloody plant, a big fat one. If it doesn't work at a hundred percent, so what. And incidentally, a lot of what I'm hearing here I have heard at the Solar Energy Society conferences where they are talking about solar collectors and reflectors and there is a group of academics out there every year that is telling us how to get another 2% efficiency in a solar collector, but no bank will give you a loan to put one on your house, so why bother with a lousy 2%. It's go, no go. Are we better off letting the Arabs get their hooks into us deeper and deeper or are we better off building a plant that isn't beautiful? I particularly enjoyed the comment about the alcohol factory, the gasohol factory, where you said, "Look, right here we may not be making any money, but we're not losing any money." The name of the game is not necessarily making money. The name of the game is survival.

I was at a conference sometime back on long-range planning, one of these cloistered things that they have in the Maine woods. We talked for a day and a half before anybody mentioned what the time frame was for long-range planning. I finally asked it over lunch. I said, "Fellows, what is long-range planning?" One of the guys said, "The time frame of long-range planning is inversely proportional to how dismally you view the future." Right now I think our long-range plan is worrying about tomorrow's survival. So don't horse around with pilot plants and experiments and that sort of thing. Get out there and build it.

"Well, I would, but." I have got the technology, I think this string is strong enough to pull the market together with the resource, but there is resistance out there. We don't know what each other is doing.

The market is capricious. It keeps moving around. We don't know about the timing. I mean we are going to find ourselves in a crash program, which is really very uneconomical, or else we might find ourselves in a position of building a plant and having it lie there for 2 years without anybody buying what we are making. We don't understand the timing.

We have got the problem of long-range planning and yet short-term survival. We don't know how big to make this plant. We really don't know what the market is because nobody has ever sold this kind of stuff before. Nobody has got a corn stover bin in his basement like they used to have coal bins. We don't know how to read that market. We are not yet used to thinking in terms of life cost rather than operating cost.

Okay. I tried to lay out the problem a little bit. Now what are we going to do about it? The government, which I remind you is us, can possibly be helpful because it's worrying about its survival and that's its job, that is why we have got a government. The government does not have expertise in marketing. I have been scratching my head for the last 2 years to figure out something that the federal government has put into channels of commerce. I give you a minute to think about it. What has the federal government ever put into channels of commerce? The only thing I could come up with was the Beltsville turkey. Maybe you can come up with something else. So we can't look to the government for marketing expertise. Okay? They can't help us much there.

Resource. We know what that is. It's land. It's there. We have got a nice fence around it which is now 200 miles wider than it was a few months ago. I don't think the government can help us much there. They have given away all that they could give away pretty much. Maybe they could let us use some that they are not using. They are using free cattle grazing or national parks. Maybe we could harvest one-fifth of every national park every year. Maybe the government could help a little over there.

Now, where the government is really brilliant is in technology. I mean they can put a man on the moon. They can't make a bathing cap that doesn't leak, but they can put a man on the moon. We don't need that kind of technology. We don't need gung ho, "damn the cost," "full speed ahead" technology. The major cost of putting solar panels on houses is the labor of local plumbers and carpenters. It doesn't have the NASA economy scale. You can't build a PERT chart that occupies billions of dollars of man-hours that the guys in Washington are so expert at. We build plants all the time without the government's help, although we are getting more help than we want. So I don't think we can look to the government for any help on the technology, not much help in the market and not much help in the resource.

We are only left with the resistance. What the devil can the government do about the resistance? Well, we heard of one state government producing some tax incentives for alcohol. If I put a solar collector on my house at a cost of 10,000 bucks, my real estate tax goes up. Does that make sense? If you take the oil out of the ground, the bank account, you get a depletion allowance and you get your head bashed in. You know, they are doing it all backwards.

Chase Manhattan Bank's February market letter said, "Don't let anybody tell you the United States doesn't have an energy policy. It has a very vivid, obvious energy policy, which is cheap energy or, in other words, the free lunch." So if the government--and recall the government is us--wants to do something, they first make the decision to stop horsing around. We do have an energy problem, it's for real. Two strikes we have got on us already, '72 and the winter of '76-'77. I don't know what the third strike is going to look like.

So let the government get in there and make some policies. We are going to give them tax incentives. We are going to let the banks give low cost loans. We had an article come out recently by a young couple, the Lavalese in Colorado Springs, who said, "The devil with this foolishness. We are going to build our own solar house. We are going to use state of the art. State of the art means anything we can learn ourselves." And they built a beautiful house. The only problem is there isn't a bank in the state of Colorado that would give them a loan on the solar part of that house. They had to take it out of their own savings.

The government can do something about that. The government can do something about patents. Did any of you notice the fact that there are very few people here that make a living by selling a product? They are staying away in droves. I came to the conclusion before I came that they probably didn't know about the conference, so I called up executives of about 10 or 12 companies, people I know, vice-presidents, presidents, said, "What are you fellows doing in biomass and solar energy?" "We are watching." "What do you watch?" "Well, you know, we don't know what the government is going to do." "Well, do you have any research and development of your own going in that area?" "No." "Well, how about getting some ERDA money?" "If you get ERDA money, they are going to want the patents." I learned over lunch today that's not true.

Finally, the one thing the government can do and they are beginning to do is to be a market. They can guarantee that if you guys can make this stuff at this price we will buy it for 10 years and we will enter into a contract that says we will. I don't care whether that stuff is gasoline or natural gas or stover or whatever it is, we can do all that. Part of the reason we don't do it is that, in the words of a corporate executive I know in Washington, infinity is 2 years. If the government is to be a market it will take a little bit of long-range planning.

So the point I would like to leave with you is simply this. We have a problem, a real problem, an energy problem, the ability to do work. That's a survival problem. The only people that are going to solve it are us and people like us. True, there aren't very many profitmaking representatives here, but there are a few. There aren't any people from Congress here, nobody from staff, nobody from state government. How come? Tell them.

The government can do a lot about communication. And incidentally, I do wish they would talk in our language instead of their language.

Okay, we have got to do something different and the best way to do something different is do something different. Dr. Kimball yesterday said he thought this meeting should have been held 5 years ago. I only hope I'm not sitting here 5 years from now talking about the same thing. The first article we published on the energy plantation was in 1972.

Finally I conclude with this thought that came over dinner last night. One of my conferees said to me, "Look, you are just asking too much. I mean, the guy has got to be an agronomist, he has got to be an entomologist, he has got to be an entrepreneur, he's got to be a mechanic, he's got to be a taxi driver, he has to be an expert on marketing corn, and now all of a sudden you want him to be a technologist and you want him to run an alcohol factory. What the devil do you call such a guy?" I call him an American.

PRESENT AND FUTURE TRENDS IN FORAGE HARVESTING EQUIPMENT

Mr. Raymond A. Adee, Vice President; R&D

The Hesston Corporation

I would like to present a brief history of some of the things we have done in our company that I think you might find interesting as it concerns the problems of handling, transporting, and storing hay crops. Our effort was directed toward finding an easier, more efficient and less expensive way of harvesting, storing and transporting hay crops particularly.

One of the processes we're interested in is cubing the crops. We did some research work, actually built some prototypes of an alfalfa hay cuber, to check the handling, the storage, transportation costs, and the problems we run into in forming a good cube that would stay together without too much fine. Our cubes had a bulk of about 30 pounds per cubic foot, so we had good bulk density. The moisture limit of the hay is 17% to 12%. That's a very narrow harvesting range because when a crop finally gets down to 17% moisture it's not going to hang there very long between 17 and 12, so it just doesn't have a broad enough harvesting range.

We had another attempt at cubing called the Rotopack. This was taking alfalfa hay, primarily, and rolling it and attempting to get a high density roll. The rolls were approximately 8 in. in diameter and could be cut to various lengths. Here again our problem was the harvesting range. For the Rotopack to work the hay had to be in the moisture range of 27% to 22%. You get a hot Kansas afternoon, why, in the morning the hay is too green and if you try and cube it, it will just turn into kind of a liquid and by the time the moisture content drops below 22% by slightly after lunch, then the hay turns to chaff.

Another thing we moved into in the late sixties and early seventies was a further attempt to do bulk handling of hay crops. We built a machine that we called the Stack Hand. The finished package from the Stack Hand looks like a large loaf of bread. The Stack Hand has been on the market since 1969 and if you have driven through the country you probably have seen these types of hay stacks. The limitation of this type of stacking is how far can you haul these large stacks economically. If you are growing hay and feeding in the immediate area of 30 miles, it's a fairly practical way to go. The density on these stacks will run from 6 to 8 lbs/cu ft. A normal bale of hay is about 8 to 12 lbs/cu ft.

One method of feeding that's used on the ranches in Kansas, Nebraska, Wyoming and other states is to slice off some hay from the large stacks made by the Stack Hand and leave this on the ground. However, I think as the value of the hay crops increases we are going to see less and less of this. There is no investment in bunks for storing the hay but you can by some estimates, save as much as 20% of the hay by putting it in bunks.

Another machine that we built was one that would stack corn stover. While we were studying the market for bulk handling of alfalfa and prairie hay, we also did some market research and determined that there's quite a substantial market of making stacks in corn stover. This turned out to be the case, but the truth of the matter is, that's just dumb luck. We just stumbled into the stacking or corn stover. I think that's something that I would like to emphasize after hearing some of the remarks during this conference about these possible projects. You can analyze, you can study and we have about concluded you do a reasonable amount of that, but if you analyze too long you will analyze it to death. You need to jump in and if it looks like it has a halfway reasonable chance and there is a need for it then go ahead and do it. Because as you get into it, you will find out a lot of things you thought were absolutes are not. There will be other pluses and minuses after you get there. We sold probably 20% more machines because of this, which was just accidental. And I daresay that's true of some of the other projects being proposed here in this room.

The stacks made with our equipment were much larger than conventional stacks. Since the stacks are so different, we have to supply the complete system for handling them. We can't just make the baler. In other words, using this equipment would change a farmers system for handling his hay.

We thought the potential for this new system would be primarily in Arizona and California. But southern California now appears to be one of the most difficult areas to change over their system. In California a lot of hay is grown and delivered to the big dairies in Los Angeles. Much of the hay is grown by individual farmers who do not bale it, so the first businessman is the farmer growing the hay. The second one is the customer contractor that bales it. Then comes along a third man who is known as a hay buyer who uses some local contractors to help load his truck at the farm end. And then he delivers to one of several dairies in the Los Angeles area. He doesn't buy from just one farmer, he will buy from as many as 25 and be delivering to 10 or 15 dairies. And then on the receiving end at the dairy he has another contractor that has a small machine that unloads off of his trucks and puts them in hay barns. So there are so many businessmen involved in this operation, each with their own equipment, that it will be difficult to change over to another system.

I would like to contrast the California situation with that of Nebraska. When we tried to market this system in the midwest, the people most interested in it were the hay growers from Nebraska. There the hay situation is different from that in California. Generally, there will be a large farmer that grows his own hay, he bales his own hay, he loads his own trucks, so he has control of about four-sixths of the operations. So there, they are ready to change over to the new system because they can do it at their own convenience. They don't have to involve a whole bunch of other people inthe changeover.

So being in the manufacturing business, this is something we look at. If you come along with an improvement, you need to consider how big a job it is to get it accepted, to get the changeover. The improvement is not going to go anyplace if you can't get acceptance and get people to make the changeover.

The Hesston Corporation also makes a processor that will take two bales and run through it with shredding knives. One of the big advantages in this system is it saves on labor at feeding time. If you have got 400 cows you are milking, with this type of processor you will spend less hours in feeding time. With conventional bales all the feeding has to be done manually.

Another aspect of harvesting equipment is the handling of forage. We have redesigned our units through the years to better handle corn and sorghum and alfalfa. Many times you will have a corn field that has a lot of grass and weeds in it which makes the corn difficult to harvest. So we have made a bulk handling machine that has disc cutoffs and gripper belts, which is designed to better handle the conventional farm crops.

We found that in areas around the world there's a real awareness of making better use of the crops they have. An example of this is the situation in Hawaii. In Hawaii the pineapple plant has a life of about 4 yrs by the time you harvest three times. Normally the plant after the last harvest of the fruit is just a nuisance. They practically wear the soil out trying to get the pineapple plant chopped up and disked up and back into the ground. Also, all the milk that's consumed in Hawaii is produced there and the feed costs are very high. For instance, corn is over $6 a bushel. So they are in a real squeeze for feed. They found out that this pineapple plant that's left, which to the landowner is just in the way, was good ensilage. They only needed a way to harvest it. Our forage harvester we found was very adaptable to harvesting the pineapple plant that is left. They were paying $40 an acre for these plants. Now there is such a demand for the pineapple plant and the pineapple people are in a price squeeze, so they are now charging $120 per acre for what used to be just a problem to get rid of.

There are some areas in Central America where they have got a surplus of sugarcane so they are chopping it for cattle feed. Sugarcane is much different than corn. Corn grows nice and straight and in line, but in many of these sugarcane fields, you have to take a machete and go out and chop to find out which way the rows run because it grows up in such thick clumps. The forage harvesting unit appears to be adaptable to sugarcane. When the sugar price is down and they have got a surplus of it some of the sugarcane growers are starting to use it for cattle feed. In other areas where they don't burn the leaves off of the sugarcane plant but harvest it without burning, the leaves are left in the field. So the Stack Hand can pick it up and stack what's left of the sugarcane plant for use as cattle feed.

(Included in Mr. Adee's presentation were slides showing various harvesting machines. Unfortunately, these slides were not available for publication.)

Working Paper - Accepted for Publication in Energy Sources

CROP RESIDUES AS ENERGY SOURCES: ASSESSING THE COST AND ENERGY FEASIBILITY OF DIRECT FIRING

Patrick J. Starr
Assistant Professor

Dean W. Finn-Carlson
Christopher J. Nachtsheim
Graduate Students

Industrial Engineering/Operations Research Division
Mechanical Engineering Department
University of Minnesota

ABSTRACT

Crop residue is a renewable resource that could supply various energy products to an agricultural region. The feasibility of such an effort depends upon agricultural characteristics of the region, the use of current energy products, alternate conversion technologies, and the operation of the supporting activities which collect, compact, ship, etc. the residue on its journey from the field to final disposition. This work delineates the various issues and shows a method of feasibility analysis which provides a uniform means of assessment of costs and energy use of alternate systems. The method is applied to examine the feasibility of direct firing residue in selected coal-fired utility boilers in Minnesota. It is found that many county-plant-operation combinations exist where the current coal cost exceeds the as-delivered cost of an energy equivalent amount of residue, suggesting that residue is a potential alternative fuel for power generation.

INTRODUCTION

It has been estimated that the yearly supply of crop residues produced in Minnesota could supply over 40% of the state's energy demand. This is a sizeable percentage, which immediately suggests a closer examination to explore the feasibility of actually using this renewable resource to meet specific energy needs. However, the notion of feasibility in this situation differs from the traditional interpretation which usually refers to the ability to accomplish a definite objective within competitive economics. This definition is easily applied when:

1. A single objective is stated.
2. The proposed system is fully specified, consisting of available hardware components .
3. The system is managed by a single organization, so all the costs/benefits can be accounted for under one umbrella.

Unfortunately, the use of crop residues for energy products does not meet these requirements. Considering the objective to be the utilization of crop residues in the most effective means one immediately runs into the problem of scope.

Many different residue types are present and are located in various densities throughout the state. Many energy oriented end uses are possible, including pyrolysis for storeable energy products, methane generation, firing for crop drying, ammonia production, and firing in local utility boilers. Each alternate use employs different technologies, which are at different levels of development. Their energy products would compete with currently available substitutes to meet specific community needs, and hence an end use choice is also coupled to location. Traditional uses are also possible, such as bedding silage and leaving in on the soil. The latter "use" holds the key to any proposed system, and while the long term effects of removal are unclear, it certainly depends upon the soil description and hence upon location. The aspects of the situation are dynamic and can change over time as traditional energy supplies diminish, as conversion technology advances and as soil properties and farm practices change. Furthermore, any operating system will involve the flow of residue through a sequence of activities involving many types of equipment which must be matched for their most economical and energy saving operation.

All these aspects raise the issue of the method for determining feasibility. There are various levels of detail that could be explored, with the final being that of an actual pilot operation. For analytical work, two levels of detail are pertinent:

a. Flow Feasibility, which refers to the accounting of the dollar costs and energy use associated with a given system assuming a uniform operation for a full year. It traces residue flow using a "tons/year" basis and accounts for the required $/year and BTU/year to sustain the flow.

b. Operational Feasibility, which refers to an investigation of the day to day operating aspects, including harvest scheduling, manpower and equipment availability, effects of weather upon storage, set-ups for the various equipment, etc. It is a more detailed look at flow feasibility to determine if there are any major factors that would bring the flow feasibility into question.

Obviously these two feasibility measures would be applied sequentially, with successful flow feasibility suggesting an investigation into operational feasibility, but an unsuccessful flow analysis suggesting a halt to further inquiry. In this work, the broad scope was reduced by adopting the realistic constraints of rapid implementation, use of local data and available technology, and utilizing a flow feasibility level of detail. Specifically, among the multiple end uses, direct firing in currently operative coal fired utility boilers was selected. This choice recognized the following issues:

a. Alternate end uses could be classified as being located "off-farm" or "on-farm" depending upon the need for loading-shipping-unloading operations. This choice is thus representative of any off-farm end use.

b. Direct firing for electrical generation supplies an established community need which can be reflected as a demand based upon actual data.

c. Deployment could be rapid, since the technology of firing crop residue is not new. However, conversion of each plant would have to be examined separately. Residue was thus treated as a supplemental fuel with the percent replacement treated parametrically with a nominal value of 20%.

d. Plants are numerous, occur in various sizes, and are placed throughout the state. This forced the analysis to accept a spectrum of residue availability, electrical demands and locations.

e. The current energy source, coal, has a wide variety of costs, ranging from about \$.35 to over \$2.00 per 10^6 BTU, depending upon the particular plant. This range suggested a locale-based economic evaluation.

f. Residue supply can be estimated from actual past yields in the area rather than inferences from more general data. However, since the effect of residue removal from the soil is unclear, the percent removed was treated parametrically with a nominal value of 15%.

This focus on a currently operational, off-farm end-use also served to organize the work into two parts. The first is an analysis of the residue supply-energy demand situation on a plant-centered basis. This produced an average shipping distance for the residue and provided a current coal cost. Feasibility for a given plant, then depends upon the dollar cost and energy use of operating the supporting activities which collect, compact, handle, ship, shred, etc. the residue as it passes from the field to insertion into the boiler. The degree to which the total costs of these supporting activities fall below the current coal cost constitutes one measure of economic feasibility. Thus, the second part is a systems study, incorporating a flow model, which accounts for the dollar costs and energy use of an entire system operating in concert on a yearly basis. Evaluating costs in such a "system", gives rise to many issues such as alternate equipment selection, alternate means of partitioning the system into sectors with various management schemes and profit incentives, and the role of modifications at existing plants. All these issues are addressed in the study. The results are twofold:

1. Presentation of a method of feasibility analysis which provides a means of uniform assessment of dollar costs and energy use of alternate systems on a local level.

2. Application of the method to examine the feasibility of direct firing crop residues in selected existing power plants in Minnesota.

ENERGY DEMAND AND RESIDUE SUPPLY

The utility boilers selected included 29 coal fired units which produce steam for electric power generation. They ranged in capacity from 6.3×10^9 to 15×10^{12} BTU/year of input energy. This range covers operations utilizing about 1 ton of coal/day to 2000 tons/day. Operational data for 1974 was obtained, including the coal tonnage fired and its heating value. The product of these two figures represented the BTU consumption and was assumed to represent the yearly "demand" at a plant. Crop residue was considered a supplemental fuel which replaced a fraction of this demand. The exact fraction depends upon a number of boiler dependent technological factors, and for the level of feasibility being investigated, a representative nominal value of the BTU replacement fraction was sought. The recent pilot operation of the St. Louis-Union Electric plant, fired by a mixture of coal and shredded-separated municipal waste, was used as an analogy. This plant uses up to 20% municipal waste. This figure was utilized as a nominal fraction of crop residue as a supplementary fuel on a BTU basis. This is a conservative value with other situations utilizing 100%

residue[1]. All residue was considered to have a heating value of 16×10^6 BTU/dry ton and contain 15% moisture by weight.

Each year the Minnesota Department of Agriculture publishes the tilled acreages of crops at the statewide, district, county and township levels[2]. The 1974 data for the seven largest crops was selected as a basis for estimating the residue supply. These included corn, soybeans, wheat, rye, oats, barley and flax, which in turn were categorized into "large grain", denoting corn, and "small grain" denoting all others. County level figures for this single year were considered both representative of a typical supply and sufficiently detailed for the level of feasibility being investigated. Crop residue yields were estimated from the tilled acreage using the values in Figure 1, which range from .378 tons/acre for flax to 2.0 for corn. These figures represent the maximum per-acre supply, but due to the undetermined effects upon the soil of removal, various removal rates were allowed, with a nominal value of 15% of the available residue used for this work. Operationally, this means that on any given acreage involved in residue collection, 100 percent of the available residue will be removed from 15% of the tilled land. Changing the collection sector each year allows for a six to seven year rotation scheme.

Since the crop residue was to be shipped to an off-farm location, the dollar and energy cost of transport had to be determined. A detailed investigation of this question would involve the location of each shipping origin and an examination of alternate origin-power plant routes. This was deemed to be both an unnecessary level of complexity and inappropriate for the level of feasibility being explored. The question was settled by presuming the tilled acreage of each crop was <u>uniformly</u> distributed throughout a county. Each county acre was considered a "representative" acre, containing the same tilled percentage as is in the country as a whole, and characterized by a residue density in terms of tons available per county acre. For example, if 20% of the land in a county was devoted to corn, the corn density would be 20% of the value in Figure 1, and this density would be further modified by the removal rate. This gives a combined measure of residue quantity and concentration. These densities thus depend upon the crop, its tilled acreage within a county, the total county size and the residue removal rate. Figure 2 summarizes the supply-demand data for typical plant-county crop combinations at various residue removal rates and supplemental fuel replacement levels.

Shipping costs are estimated by considering a plant to be the origin of a circle surrounded by representative acres of a particular county, and computing a supply radius, R. representing the maximum radius of influx needed to support the demand on a continual basis. The shipping radius, $\bar{R}$, is estimated by computing the average straight line distance from the origin to any point within the supply radius and is given by $\bar{R} = R/\sqrt{2}$. This average shipping radius is used in conjunction with a value of cost/ton-mi to determine shipping expenses.

Figure 3 shows the relationship between the supply radius, the demand, and the residue density. This figure in conjunction with Figure 2, can be used to estimate the supply and shipping radii for various plants, fuel replacements and removal rates. For example, to supply the Fairmont plant with corn residue would require a supply radius of about 9 mi. with 100% BTU replacement and 15% residue removal, but it would decrease to 3 mi. with 100% removal. Note that if densities are considered to range up to the values in Figure 1, then Figure 3 applies to the energy farm concept, where a firing unit is surrounded by tilled acreage.

FLOW MODEL: OVERVIEW

A system flow model was developed as a basis of accounting for the dollar and energy consumption associated with each operation involved in moving residue from the field to a boiler. The approach assumed that residue is available in the field after cash crop harvesting has been completed. The effect of this starting point is to exclude the dollar and energy costs associated with field preparation, planting, and cultivating of the crop that produces the residue. This was assumed to be a legitimate starting point as these operations are already charged as the cost of producing the cash crop. Also, the approach only takes into account the energy required to operating the machines making up the system. It does not account for the energy required to construct the machinery and provide building materials, since it was desired to determine whether it would be energy feasible to use existing machinery in the collection, transport, and processing of residues for use as fuel. The crop residues were treated in the two previously mentioned categories of large grains (corn) and small grains since each require different processes to prepare them for collection, and equipment capacity is directly related to the amount of residue available per acre, which for corn, averages about two and one-half times as much as the small grains.

The flow model consists of a sequence of activities, some or all of which are required to remove the residue from the field and deliver it to the boiler in useable form. Ten possible sequential stages were identified as composing this sequence and are shown in Figure 4 as grouped into three major sectors. Within each stage, there are numerous types of equipment, or "operation blocks", which could perform the task. The numbers in parenthesis indicate the number of different operation blocks at each stage. As residue flows through an operation block, there results a consumption of energy and dollars as measured in terms of fuel cost use, man-hours, twine footage, and investment and operational costs for the respective equipment. For each operation block (149 were identified), this data was gathered, and using accepted means, was converted to units consumed per ton of residue flow. The operations could also alter the form of the residue, which included small bales, roll bales, three sizes of stacks and the shredded form. It was presumed that when the residue leaves stage 10 and enters the boiler, it had to be in the shredded form.

The term "strategy" was used to describe a particular sequence of operation blocks, one at each stage, and a strategy was evaluated by determining the total dollar and energy costs for the simultaneous operation of all the chosen blocks. Obviously, there are numerous possible strategies, involving varying degrees of labor, energy and capital intensity. The flow model format provided a means for identifying and equitably comparing the numerous strategies, with each operation block treated in the same manner, and facilitating both the collection of data and the accounting of dollar and energy consumption. This level of feasibility is necessarily rough, avoiding such items as harvest scheduling, manpower and equipment availability, and weather effects, but if a system is not flow feasible, it is useless to explore these further details of the day to day operation. The model does include storage activities, both on the farm and an explicitly constructed storage facility at the power plant.

FLOW MODEL: DETAILS

This section describes the manner in which energy use and dollar costs were determined in the various operation blocks.

Individual Operations

The activities of each stage can be accomplished in a variety of ways depending on the machinery used with a total of 149 different operations being identified. Each block in one stage cannot necessarily interact with all the others in the following stage since different forms of residue are produced by the various available collection machinery. It was necessary to monitor the forms because their storage and handling characteristics differ according to size and density which are outlined in Figure 5. Within each stage, (except storage), each operation block was treated as a flow element which could transform the form of the residue and consume resources. Figure 6 shows the general flow model used for each operation block. Four coefficients were associated with each block, indicating the amount of fuel, twine, man-hours, and ownership cost that are required to support the flow.

Flow Coefficient Determination

Ownership cost was calculated using accepted methods of the ASAE[3], and was composed of three parts: depreciation, fixed costs, and maintenance and repair. Straight line depreciation over the life of the machine in hours was used with a salvage value of zero assumed. Fixed costs were: interest on the remaining value, insurance, taxes, and housing for the machinery. Total life value of these fixed costs was assumed to be 6 per cent of the purchase price of the machine.

Repair and maintenance costs were calculated as per Reference 3. The result of adding these three costs together was a dollars per machine-hour cost of ownership. A consequence of basing the cost on the useful life of the machinery is that an ownership cost is only incurred if the equipment is active.

The fuel consumptions, in gallons per machine hour, of appropriately sized power sources within the operation blocks were taken from Nebraska Tractor Test Data[4], and machine-hours per ton and man-hours per ton were computed under the following assumptions.

1. As a statewide average, small grain harvesting operations result in windrows of residue spaced 13.5 feet center-to-center.

2. The fastest way to process corn residue for collection was to chop up the stalks using a rotary cutter and then rake the chopped material into windrows.

3. Stackwagons can collect the corn residues as left by the harvesting operation.

4. Single-unit trucks were realized 9.36 mpg[5], maximum tractor road speed was 15 mph, and maximum truck road speed was 40 mph.

5. Machinery field operating speeds and field efficiencies were averages taken from Reference 3.

The interactions of field speed, field efficiency, windrow width, and tons of residue per acre combined to give a measure of the number of machine hours per ton required to carry out the action of a particular operation block for the stages of Precollect, Collect and Retrieve. For the other operation blocks, except those in stage 6 (Ship) the interaction of average distance traveled, average load carried, and average speed combined to give a measure of required machine-hours per ton. The labor requirement, in man-hours/ton was computed from the machine-hours/ton requirement and the number of men required to handle the machines and material produced. The fuel consumption, in gallons per machine-hour and the ownership costs, in dollars per machine-hour, were multiplied by the appropriate machine-hours per ton figure for that block to arrive at a gallons per ton and a dollars per ton characteristic.

For shipping, stage 6, coefficients were developed in terms of units per ton-mile by dividing the various parameters ($/hr., gal/hr., etc.) by the average road speed and average load in tons of the equipment composing the operation block. Actual dollar and energy consumption then utilized the average shipping radius, $\overline{R}$, for a particular site.

Two types of storage facilities were considered: silo storage and flat surface storage, each incurring an ownership cost. The size of storage was determined from the number of days supply of residue that were to be inventoried which was taken as 90 days. The cost per ton of a specified type and size of storage facility was determined using the construction cost, a 20 year lifetime and the residue flow.

EXCLUSIONS

During model construction, certain items were considered for inclusion and subsequently either discarded or treated in an indirect manner.

Drying and Transshipment

No residue drying operation was included, since collected residue was assumed to contain only 15 to 20 per cent moisture. This is low enough so that pile heating and spoilage, both of which result in a degradation of the residue BTU content, are negligible. In addition, this moisture content presents no problems for grinding or firing the residue in the boiler. The presently available grinding equipment, the characteristics of which were used in the model, are all designed to normally operate on materials with this moisture content. Also, low grade coal can run as high as 30 to 40 per cent moisture and coal of this type is routinely fired without problems.

No transshipment activity was included as all the shipping radii were small. It was decided that, considering these short distances (usually less than 13 miles), the dollar and energy costs of two more handling operations, loading to an unloading from the transshipping vehicles, would more than offset any savings realized by utilizing a more efficient mode of transportation.

Boiler Modification Costs

Figure 4 shows that stages 1-7 are required to collect and deliver residue to a power plant and stages 8-10 occur at the plant. There is one more stage which is not explicitly considered, but certainly plays a role: Boiler Modifications. This refers to an amortized first cost and possibly an operating cost of performing the modifications necessary to adapt a boiler to the firing of residue as a supplementary fuel. This only includes modifications to the boiler itself, since stages 8-10 account for the at-plant preparatory operations of unloading, storing and shredding-blowing the residue. Thus, two categories of possible modifications at the plant were defined:

Plant Modifications, which refers to all changes needed at a plant in order to use residue as a supplemental fuel. These modifications include the activities of stages 8, 9, 10, dealing with unloading, storing, and grinding, and boiler modifications.

Boiler Modifications, which refers only to necessary changes to the boiler itself.

Originally, it was intended to estimate the boiler modification costs, but the uniqueness of each boiler installation foiled an attempt to categorize the units on a "needed modifications" basis within the time frame. Of course, firing residue is not new technology, but assessing modification costs is an individual matter for each boiler. Modifications could run from virtually nil in a cyclone type boiler to cutting into the side, sealing some water pipes, setting up controls, etc. The exclusion of such costs does not imply that they were neglected. Fortunately, this was the only operation that could not be costed on a uniform basis, so as will be discussed shortly if a strategy is termed "system feasible", it will imply that a supply of funds is available on a yearly basis which could be allocated to boiler modifications.

Management and Profit

The ability to assess the entire operation raises issues as to the manner in which the dollar costs were established. Considering the system as a whole, many types of management schemes are possible, from a fully integrated system with a single organization directing all the stages of activity to at least three individual entrepreneurs directing the On Farm, Shipping and Plant sectors respectively. Furthermore, the role of profit incentive may vary, from an integrated corporation viewpoint, to the three entrepreneurs, or a cooperative, which is familiar in many rural areas. In the setting of these diverse management schemes, the accounting scheme used herein focused only on the dollar costs needed to own and operate the various alternative systems. Costs are incurred for labor, fuel, twine and equipment ownership including depreciation, fixed costs and maintenance. There was no value added to any operation which would reflect additional economic incentive or managerial expenses. Thus the cost figures obtained represent the actual direct costs to own and operate a particular strategy on a dollars/year basis.

EXPLICIT MEASURES OF ECONOMIC FEASIBILITY

Two measures of economic cost feasibility are considered; one treats a "system" as including only stages 1-7, comprising the On Farm and Shipping sectors. The associated cost/ton of residue would be the as delivered cost to the door of the power plant. If this were less than an equivalent BTU amount of coal, the associated system is termed Delivery Feasible. This viewpoint treats all associated power plant costs as "outside" the system, letting any required modifications become the concern of the plant. Thus, the difference between the cost/ton or residue and an equivalent amount of coal, multiplied by the residue throughput would yield a dollar/year value that could be distributed as an incentive among the On Farm and Shipping sectors, and used to fund the necessary modifications to the plant.

Another measure is System Feasibility, which describes the situation when all the stages, 1-10, yield a cost/ton value that is less than an BTU equivalent amount of coal. In this case, the cost difference would produce a revenue to be distributed both as an incentive to each sector and supply funding for only boiler modifications, since the plant modifications of stages 8-10 are already included in the cost. Obviously a strategy that is System Feasible will be Delivery Feasible, but not necessarily vice versa.

It was recognized that these measures of feasibility do not produce clear-cut recommendations, but it must be acknowledged that with many possible management schemes, and with various views on the utility of energy production and supply, there is room for a diversity of opinion as to the role of monetary incentive. Also, the responsibility for plant modifications may be legitimately viewed as "outside" the energy supply system. For these reasons, the feasibility measures employed focused only on actual costs which must be incurred. A feasible system in this interpretation is then one which makes available a yearly flow of funds produced by the difference between the current cost of coal and an equivalent amount of residue. These funds could be used to provide incentives at various stages in a system and to make appropriate modifications at a plant. Whether or not these funds are indeed sufficient depends upon the various entrepreneurial actors in a system and the current situation at a power plant. Obviously a cooperative management scheme for a small plant may find the funds sufficient, but the same system, operated by a sequence of individual entrepreneurs with different economic incentives may not. Naturally, a strategy that makes more funds available is realistically potentially "more feasible", so this viewpoint does provide a means of comparing alternate strategies on this basis.

RESULTS

The following summarizes the results of applying this method of feasibility analysis to selected coal fired plants in

Minnesota. Of the 29 plants considered, those with a yearly energy consumption below 2.5 x 10^{12} BTU/year and located in "farming areas", could be supplied with 20% supplemental fuel using 15% of all available residue from an area within a 13 mile radius of the plant. With 100% fuel and 15% removal, the radii do not exceed 29 miles. This suggests that transshipment is unnecessary, and also that local supply of fuel is possible.

Thirty-eight (38) alternate strategies were examined, encompassing the forms of small bales, roll bales and stacks, and split among two representative power plants. Fifteen (15) different corn strategies were run, based on the Red Wing plant and 24 different small grain strategies were run, based on the Crookston plant. The parameter values used in all cases are shown in Figure 7, and the average supply radii were under 10 miles. As an example of typical strategy, Figure 8 shows the detailed operation blocks for a roll bale operation. This format illustrates the distribution of fuel, labor, twine and capital on a per-ton basis. Figure 9 summarizes the cost and energy flows associated with the yearly operation on a sector by sector basis.

Similar analyses were performed for all strategies and Figures 10 and 11 summarize the cost and fuel use for the collection-delivery stages (1-7) and the system wide operation (1-10). Each point represents a different strategy, with the previous one denoted by point A. Cost scales are shown in dollars/ton of residue and dollars/million BTU, assuming 16 x 10^6 BTU/dry ton and 15% moisture. The delivery system cost/ton ranged from \$4.67 to \$10.17 and the delivery system cost/ton ranged from \$7.75 to \$14.55. System wide energy consumption was always less that 4% of the potential heat energy contained in the 15% moist residue. In terms of fuel consumption, the delivery system use ranged from 1.19 to 2.89 gal/ton. The system wide fuel consumption ranged from 2.17 to 4.16 gal/ton. Exhaustive searches among all strategies were not attempted, so patterns should not be interpreted too rigidly, but certain cursory observations can be made from the data clusters. Roll bale systems result in lowest cost while small bale systems give the highest costs. Stack systems are used more efficiently with the higher density corn residue.

CONCLUSIONS

A method of accounting for dollar and energy costs of alternate combinations of operations to support the collection, shipping and preparation of residue for firing was developed and applied to representative utility boilers in Minnesota. The method treated each activity as a flow element which could consume labor, twine, fuel and ownership costs on a per-ton basis. Yearly flows were considered with a 15% residue removal rate and its use as a supplemental fuel supplying 20% of the BTU consumption at a plant. Ten separate stages of activities were identified, each performing a different function, and these were grouped into the three sectors of On Farm, Shipping and Plant. The analysis utilized a uniform means of accounting, so comparisons could be made both among the different strategies and among the different sectors. Energy use and dollar costs for various strategies were summarized graphically.

The methodology is of importance in itself since the situation is not unique to crop residue utilization. The issues raised in this application and their resolution, within a framework of realistic assumptions and uniform analysis, are thus prototypical of a responsible feasibility analysis requiring the equitable evaluation of alternate technologies in an environment of regionally influenced supply and product demand. For example, Figure 3 can give an estimate for shipping radii under a variety of circumstances, due to the flexible manner in which density can be interpreted, and Figure 10 can apply to any end use where residue is being supplied to an off-farm site under the previously given supply-demand conditions.

Specific results were given for typical sized plants, and it was shown that when considered on a per-year flow basis, the cost of owning and operating a system which supplies local residue to a plant could be competitive, especially with selected roll bale equipment. The lowest cost strategy incurred costs of \$0.34 per 10^6 BTU for residue delivered to the plant (stages 1-7) and \$0.57 for a system wide operation (stages 1-10).

Such systems are efficient energy users, consuming only 2%-4% of the energy potential in the residue.

The cost figures compare favorably with the \$.35-\$2.00 per 10^6 BTU range for coal. A difference in cost of \$0.10/10^6 BTU translates into \$1.36/ton, so these figures can be used to determine the available returns on a residue flow basis. For example, a current coal cost of, say \$1.50/10^6 BTU, compared to the system wide cost of a typical corn strategy using stack wagons of \$0.75/10^6 BTU would yield a difference of \$10.20/ton over and above the labor, fuel, ownership and maintenance costs. Since the costs considered did not include a profit at any stage, an entrepreneurial cost nor boiler modification costs, the difference could be utilized for these purposes. The methodology provides a means of viewing these aspects in perspective and identifying their proper role in a feasibility determination.

However, it is well to remember that such a system does pay for itself in terms of labor, fuel, twine, equipment and maintenance. Also, one must acknowledge that some staff at the plant are already doing ordering and scheduling of fuel shipments, and so a dimension of the management is being accomplished. Realistically, while one may not become wealthy with such a system when coal costs are below around \$1.00/10^6, a breakeven operation could be envisioned. And, it could have certain, non-economic aspects, such as local off-season employment opportunity, local cooperative management, and meeting a local energy need with a local resource, which would lessen the dependence upon the vagaries of the outside energy market. Such a system could provide a viable alternative to depleting fuel supplies and a means of encouraging community involvement.

ACKNOWLEDGEMENTS

This work was sponsored under matching grants from the Minnesota Pollution Control Agency and the University of Minnesota.

REFERENCES

1. D. A. Vaughan, Information via Personal Communication, Corrosion and Electrochemical Division, Battelle Columbus Labs, Columbus, Ohio. (1976)

2. Minnesota Crop and Livestock Reporting Service, 1974 Minnesota Agricultural Statistics, Minnesota Department of Agriculture, Metro Square Building, St. Paul, Minnesota.

3. American Society of Agricultural Engineers, "Agricultural Machinery Management Data", in 1973 Agricultural Engineering Yearbook, pp. 314-321.

4. Nebraska Tractor Test Data - 1974, University of Nebraska - Lincoln, Department of Agricultural Engineering, Lincoln, Nebraska.

5. 1974 Motor Truck Facts, Motor Vehicle Manufacturers, Association of the United States, Inc., 366 Madison Avenue, New York.

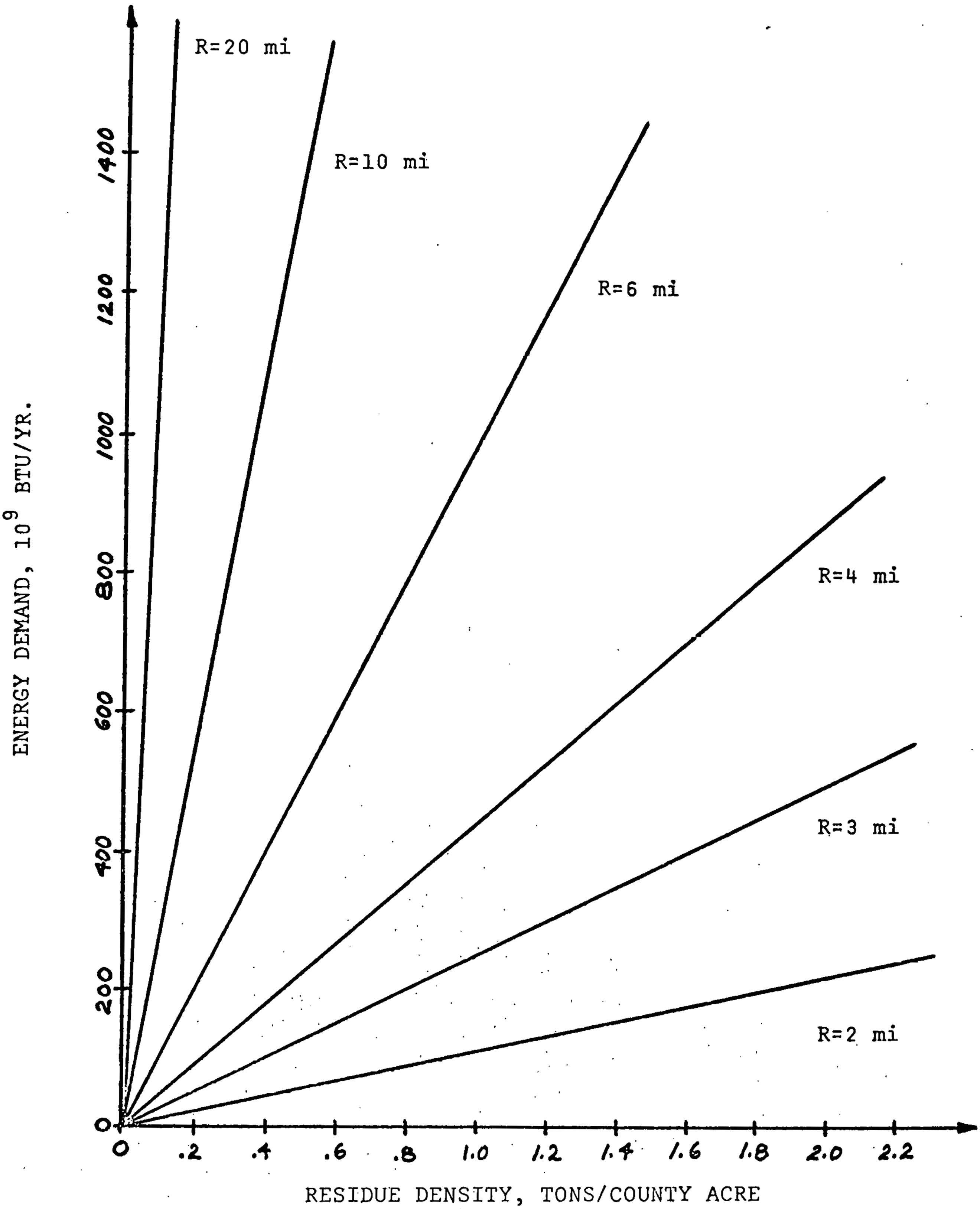
FIGURE TITLES

CROP	RESIDUE, TONS/ TILLED ACRE
Soybeans	.870
Corn	2.604
Wheat	1.167
Rye	.980
Oats	.896
Barley	1.080
Flax	.378

Fig 1
P. Starr

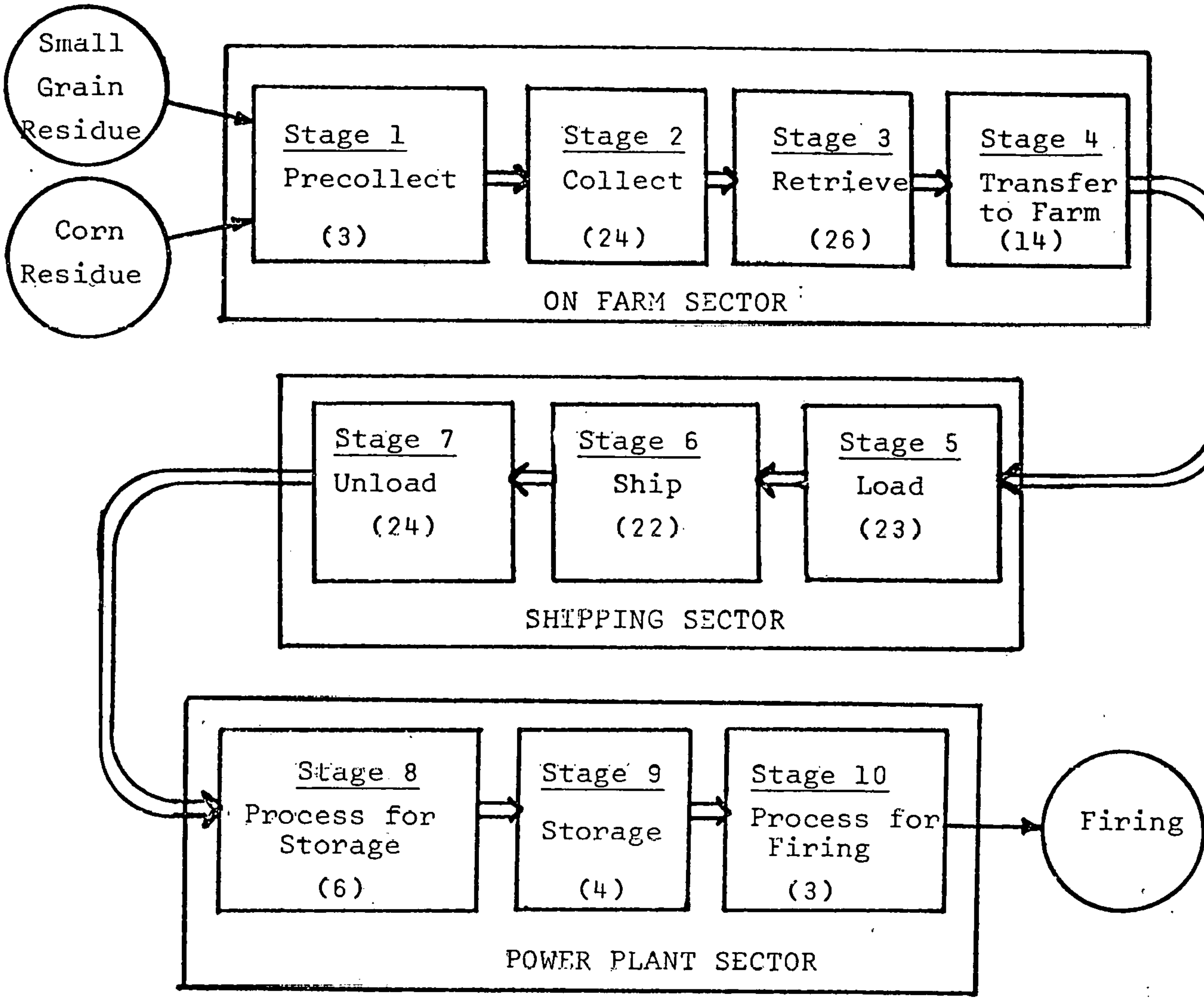
		DEMAND (10^6 BTU/YEAR)			CORN DENSITY (TONS/COUNTY ACRE)			DENSITY(ALL)(TONS/COUNTY ACRE		
PLANT	COUNTY	20% REPLACEMENT	60% REPLACEMENT	100% REPLACEMENT	15% REMOVED	30% REMOVED	100% REMOVED	15% REMOVED	30% REMOVED	100% REMOVED
ALEXANDRIA	DOUGLAS	15,220	45,660	76,102	.048	.095	.318	.087	.175	.583
BLUE EARTH	FAIRBAULT	17,260	51,778	86,297	.130	.259	.864	.194	.389	1.298
BEMIDJI ST	BELTRAMI	36,000	108,000	180,000	.0005	.0010	.0034	.002	.005	.016
CROOKSTON	POLK	98,428	295,285	492,142	.006	.012	.039	.083	.166	.553
ELK RIVER	SHERBURNE	189,344	568,000	946,720	.040	.079	.264	.054	.108	.363
FAIRMONT	MARTIN	48,400	145,200	242,000	.145	.290	.966	.204	.410	1.365
FERGUS FALLS	OTTERTAIL	1,949,186	5,847,560	9,745,932	.034	.068	.227	.067	.135	.448
RED WING	GOODHUE	118,332	354,998	591,663	.091	.182	.608	.116	.232	.774
ROCHESTER	OLMSTEAD	502,180	1,506,540	2,510,901	.089	.178	.595	.114	.227	.758

Fig 2
P.5422



R=20 mi
R=10 mi
R=6 mi
R=4 mi
R=3 mi
R=2 mi
ENERGY DEMAND, 10^9 BTU/YR.
0
200
400
600
800
1000
1200
1400
0
.2
.4
.6
.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
RESIDUE DENSITY, TONS/COUNTY ACRE

Fig 3
P. Starr



DESCRIPTION OF STAGES

1. PRECOLLECT: Prepare loose residue to a form suitable to be picked up by a baler or stackwagon.
2. COLLECT: Pick up loose residue from the field and create bales or compacted stacks.
3. RETRIEVE: Stack residue packages for later pickup or pick up bales or stacks from field for transfer to farmstead.
4. TRANSFER TO FARM: Move bales or compacted stacks to the farmstead, unload, and stack.
5. LOAD: Load residue onto long haul shipping equipment.
6. SHIP: Transfer residues from farm to place of use.
7. UNLOAD: Unload residue into storage facility or onto dumping ground.
8. PROCESS FOR STORAGE: Prepare residues for storage.
9. STORAGE: Specify size of residue inventory and type of storage facility to be used.
10. PROCESS FOR FIRING: Prepare residue for injection into boiler feed system.

Fig. 4
P. STARR

FORM	AVERAGE SIZE	AVERAGE WEIGHT (lbs)	AVERAGE DENSITY (lb/ft^3)	TWINE USAGE (ft/bale)
Shredded	---------------	---	3.5	---
Small Bale	14" x 18" x 42"	60	9.6	19
Roll Bale	6' dia x 5' long	1350	9.5	197
3 Ton Stack	15' x 7' x 11'	6000	5.0	---
6 Ton Stack	20' x 8' x 11'	12000	7.6	---
8 Ton Stack	16' x 12' x 15'	16000	6.5	---

Fig 5
P. Starr

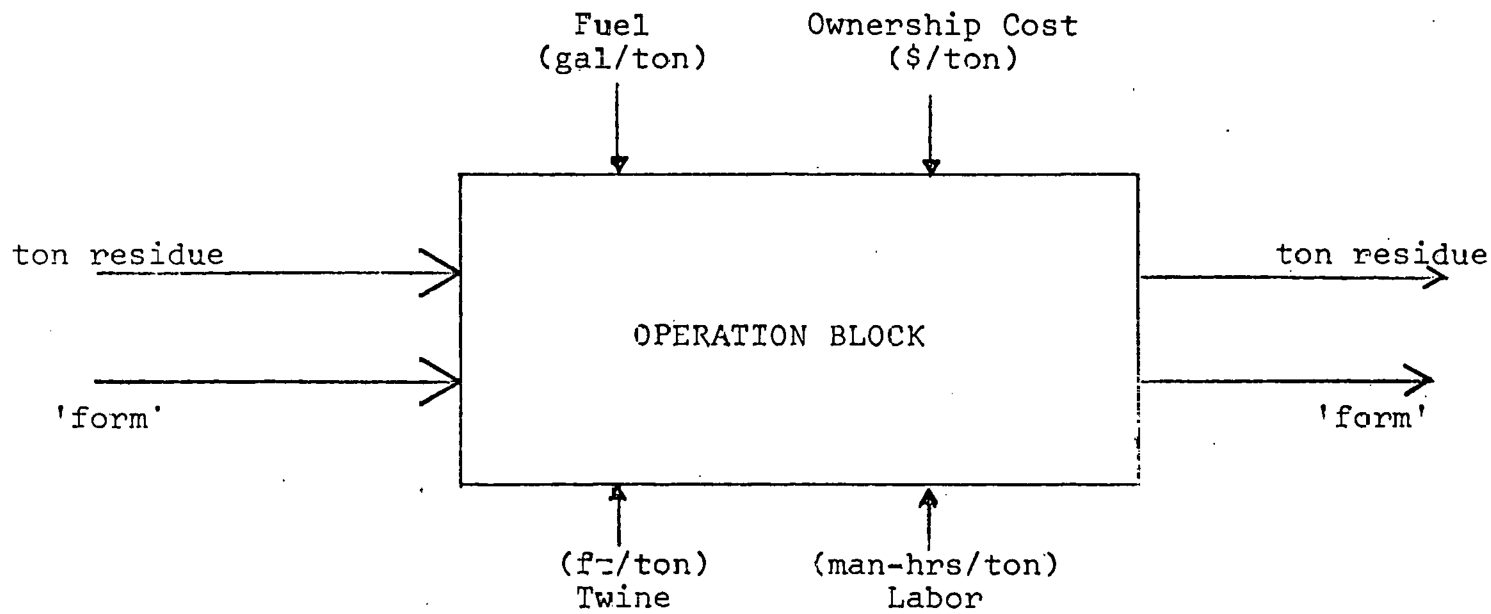
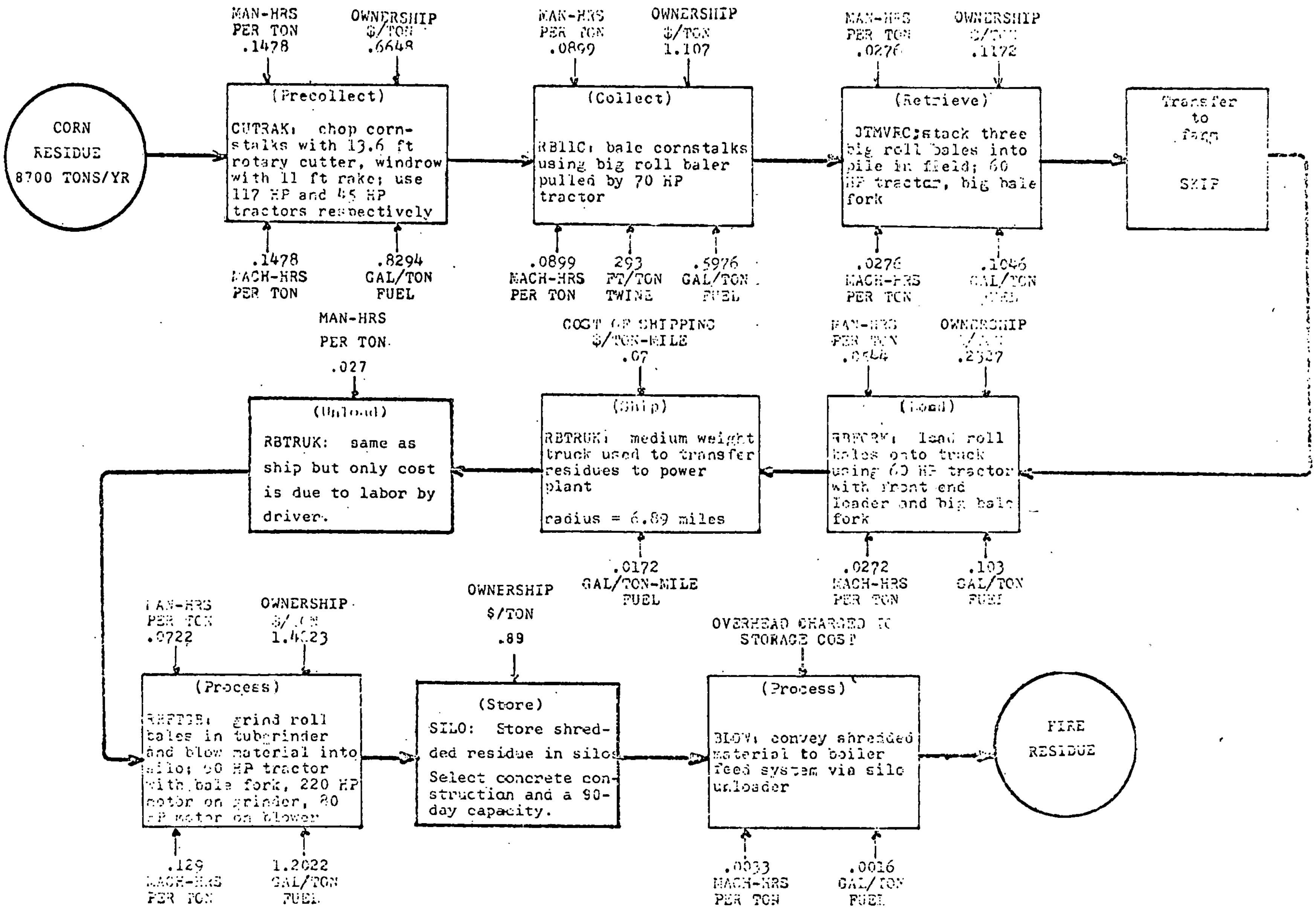

Fuel
(gal/ton)
Ownership Cost
($/ton)
ton residue
'form'
OPERATION BLOCK
ton residue
'form'
Twine
(man-hrs/ton)
Labor

Fig 6
P. Starr

Residue energy value	16,000,000 BTU/dry ton
Residue moisture content	15%
Tons of residue/tilled acre	Figure 1
Residue removal rate	15% of available
Cost of twine	$3.57/1000 ft
Cost of labor	$2.50/hour
Cost of fuel	$.50/gallon
BTU fraction supplemented	20%
Storage inventory at plant	90 days

Fig 7
P. Starr



CORN RESIDUE 8700 TONS/YR
MAN-HRS PER TON .1478
OWNERSHIP $/TON .6648
(Precollect)
CUTRAK: chop cornstalks with 13.6 ft rotary cutter, windrow with 11 ft rake; use 117 HP and 45 HP tractors respectively
.1478 MACH-HRS PER TON
.8294 GAL/TON FUEL
MAN-HRS PER TON .0899
OWNERSHIP $/TON 1.107
(Collect)
RB11C: bale cornstalks using big roll baler pulled by 70 HP tractor
.0899 MACH-HRS PER TON
293 FT/TON TWINE
.5976 GAL/TON FUEL
MAN-HRS PER TON .0276
OWNERSHIP .1172
(Retrieve)
JTMVRC: stack three big roll bales into pile in field; 60 HP tractor, big bale fork
.0276 MACH-HRS PER TON
.1046 GAL/TON
Transfer to farm
SKIP
MAN-HRS PER TON .0564
OWNERSHIP .2327
(Load)
load roll bales onto truck using 60 HP tractor with front end loader and big bale fork
.0272 MACH-HRS PER TON
.103 GAL/TON FUEL
COST OF SHIPPING $/TON-MILE .07
(Ship)
RBTRUK: medium weight truck used to transfer residues to power plant
radius = 6.89 miles
.0172 GAL/TON-MILE FUEL
MAN-HRS PER TON .027
(Unload)
RBTRUK: same as ship but only cost is due to labor by driver.
PER TON .0722
OWNERSHIP 1.4023
(Process)
grind roll bales in tubgrinder and blow material into silo; 60 HP tractor with bale fork, 220 HP motor on grinder, 80 HP motor on blower
.129
PER TON
1.2022 GAL/TON FUEL
OWNERSHIP $/TON .89
(Store)
SILO: Store shredded residue in silos. Select concrete construction and a 90-day capacity.
STORAGE COST
(Process)
BLOW: convey shredded material to boiler feed system via silo unloader
.0033 MACH-HRS PER TON
.0016 GAL/TON FUEL
FIRE RESIDUE

FIGURE 8

300

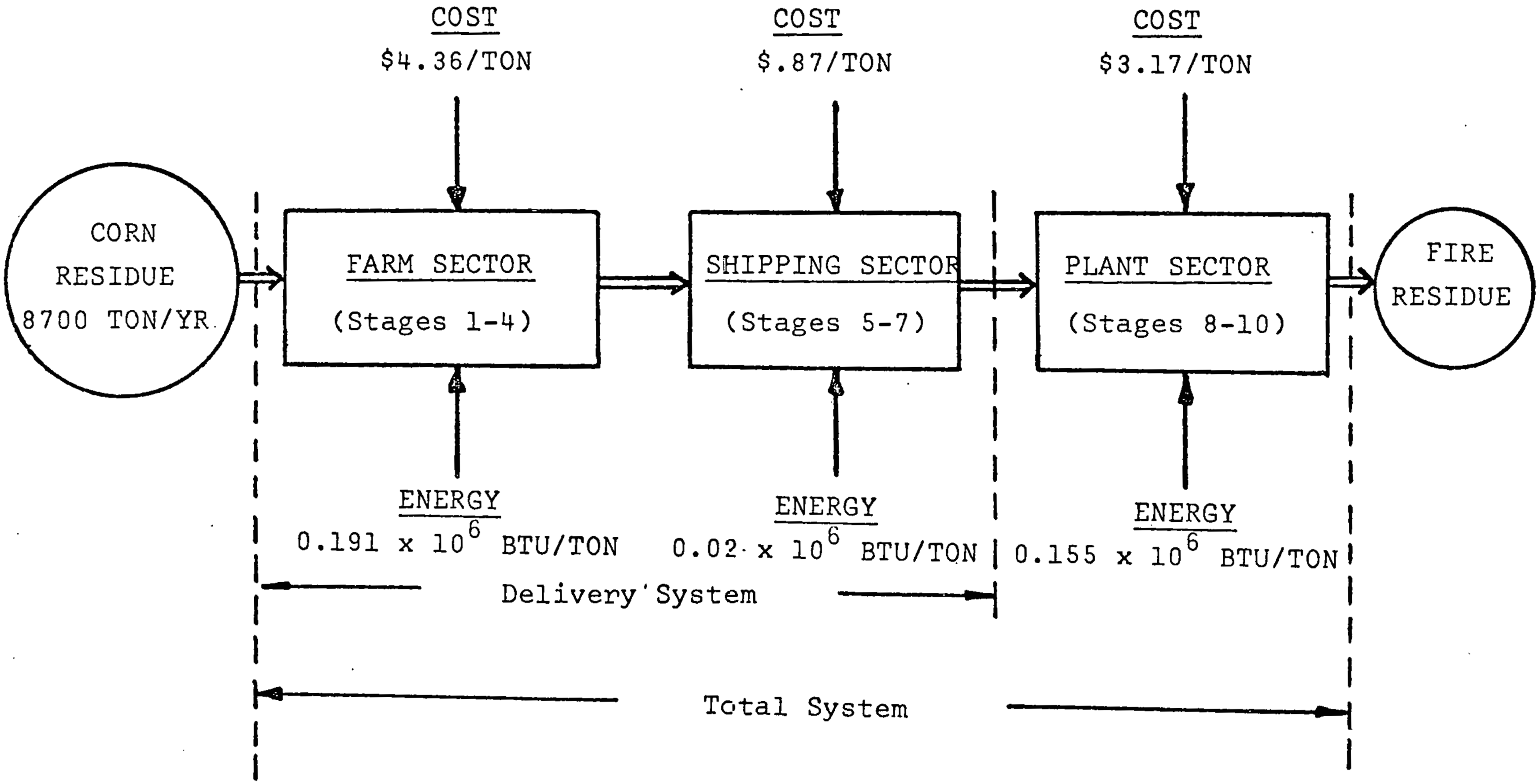

COST
$4.36/TON
COST
$.87/TON
COST
$3.17/TON
CORN
RESIDUE
8700 TON/YR
FARM SECTOR
(Stages 1-4)
SHIPPING SECTOR
(Stages 5-7)
PLANT SECTOR
(Stages 8-10)
FIRE
RESIDUE
ENERGY
0.191 x 10^6 BTU/TON
ENERGY
0.02 x 10^6 BTU/TON
ENERGY
0.155 x 10^6 BTU/TON
Delivery System
Total System

Fig. 9
P. Starr

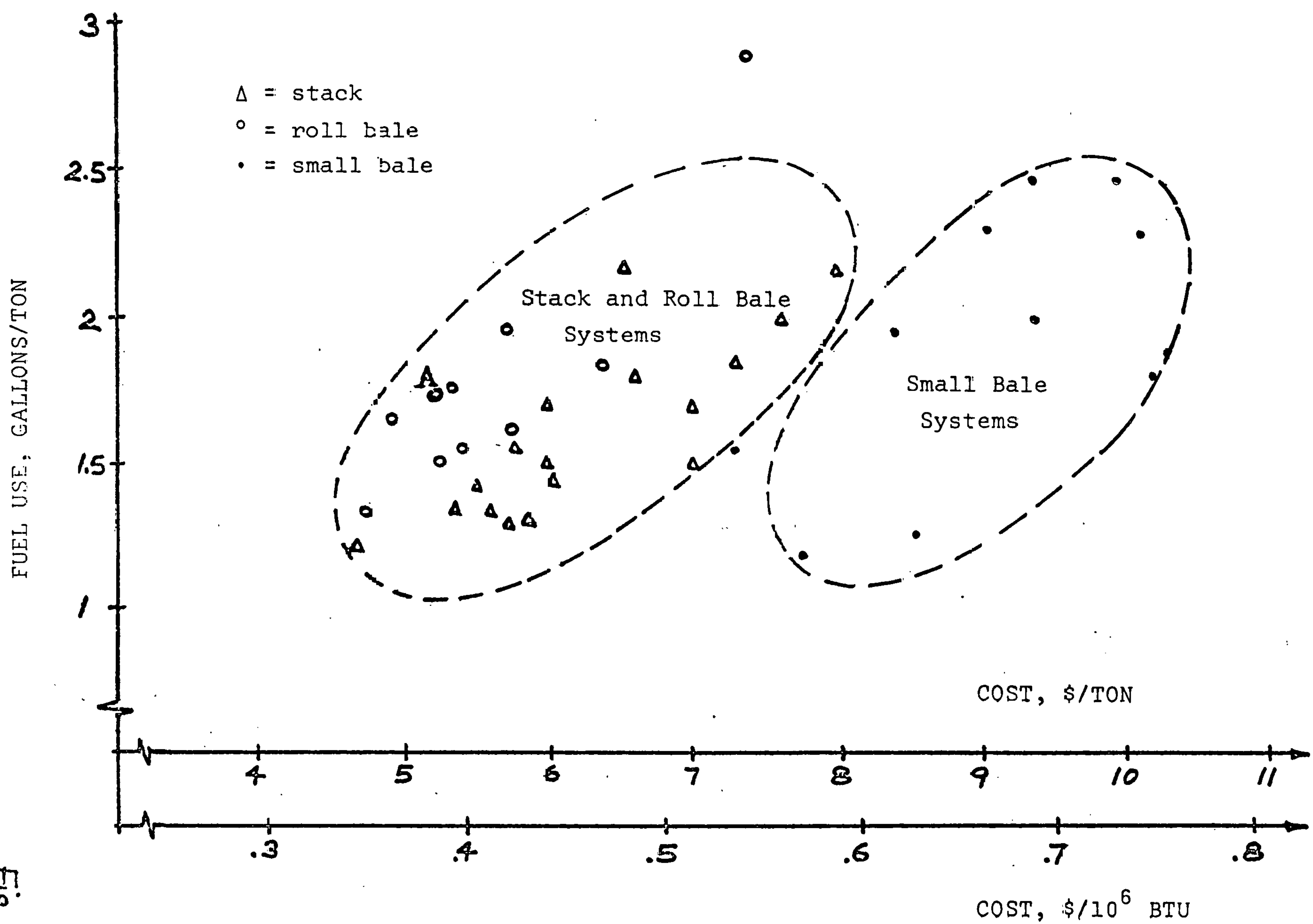
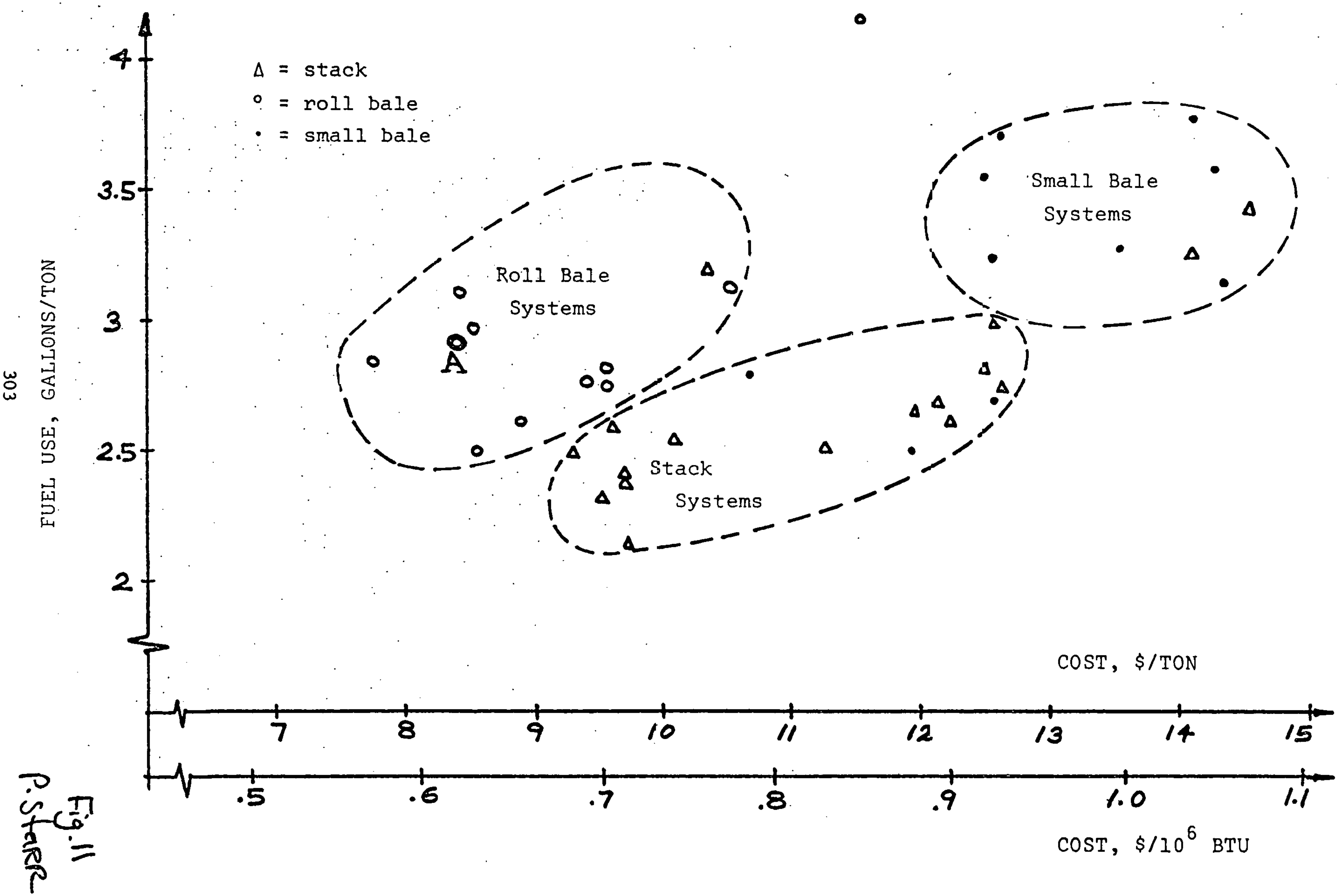


Fig. 10
P. Starr


Δ = stack
° = roll bale
• = small bale
Roll Bale Systems
Stack Systems
Small Bale Systems
A
FUEL USE, GALLONS/TON
4
3.5
3
2.5
2
COST, $/TON
7
8
9
10
11
12
13
14
15
.5
.6
.7
.8
.9
1.0
1.1
COST, $/10^6 BTU
Fig. 11
P. Starr

USE OF CROP RESIDUE TO SUPPORT A MUNICIPAL ELECTRIC UTILITY*

by

N. Dean Eckhoff

in collaboration with

William H. Johnson
Thomas W. Lester
Richard K. Koelsch
Stanley J. Clark
George H. Larson

I. Introduction

The Pratt Problem

Pratt, Kansas is a medium-to-small sized city, the county seat of Pratt county, located in the south central part of Kansas about 80 miles west of Wichita. The approximate 6500 Pratt citizens depend, primarily, on their municipally-owned electric generating plant and, secondarily, on an interconnection with the Western Power Division of the Central Telephone Utilities, for their electrical service. The present approximately 25 MWe plant is fueled with natural gas, and fuel oil is used as a back-up fuel source.

Fuel supply for Pratt has not been a problem until recent years when they, like many other large natural gas users, have experienced nagging interruptions in service. In fact, Pratt officials have been alerted to the fact that a continuing supply of natural gas will not be available. The back-up fuel supply is expensive and likely supplies will be unavailable or scarce in the near future. Also buying bulk power from other utilities is just too expensive because of the long distance between Pratt and any "secure" electrical generating plant. Therefore, Pratt officials must find fuel supplies with which to maintain their electrical generating independence. Options are limited with a conversion to coal being the most obvious. However, renewable energy source options should be carefully studied before a committment is made.

Kansas, a Wheat State

Kansas farmers plant about 11 million acres per year to wheat, from which they produce about 350 million bushels of wheat annually. Wheat is very important to the Kansas economy. While present varieties of wheat are not very efficient biomass producers, we estimate that at least an average of 20 pounds of wheat straw per bushel of wheat can be removed for other uses without seriously impacting soil conditions, i.e., depleting humus, promoting more water evaporation, or promoting more wind erosion.

*Primary funding for this study was provided by the Ozarks Regional Commission.

Kansas, Rich in Renewable Energy Sources

Kansas is rich in renewable energy sources. For example, Kansas receives daily solar energy which is about 3.5 times its total annual energy requirements, i.e., 3.2×10^{15} Btu from solar energy are received daily and about 0.9×10^{15} Btu of various energy types are consumed annually. Additionally, in about 5 hours of average wind conditions, Kansas receives the equivalent of its annual energy requirements in the form of wind energy. Of the solar energy received annually at least 5% of the annual energy requirements of Kansas are stored in "removable" wheat straw. With the development of new varieties of wheat and new farming techniques, we could easily increase this percentage to 25% to 50% of our energy needs. There are, of course, other crops which produce residues capable of being used as an energy source; some are much more efficient at biomass production than is wheat. For example, Kansas-grown sorghum can produce annually about 17 tons of biomass per acre, most capable of being removed; contrast this to the 0.3 ton of removable wheat straw produced annually per acre.

Pratt Fuel Options

North of Pratt, about 5 miles, is a 35,000 head feedlot, which produces annually a minimum of 50,000 tons of burnable refuse. This material is capable of producing about 30% of the average electrical needs of Pratt's citizens. Additionally, the citizens of Pratt produce an average amount of municipal refuse and sewage sludge. These materials are probably able to produce about 5% of 10% of Pratt's total electrical needs.

Any fuel options inquiry must recognize the existence of competitive markets for the various energy resources. Coal must be obtained in direct competition with other fuel purchasers. Contract negotiations are generally keen and require considerable skill, especially when high-Btu, low-sulfur coal is under consideration. The use of solar energy requires a substantial investment by the individual users. In fact, Pennsylvania Power and Light who shared recently, via Electrical World, experiences of their insulation and energy use efficiency improvement program indicate that after a proper upgrading of the building envelope and heating system a modest solar system would require between 53 and 67 years to payback via reduced energy costs. The system they describe would cost, by their estimates, between $6,250 and $10,000. There are no central station solar or wind systems commercially available. Wind systems for individual homes are estimated to cost even more than solar systems for individual homes. Thus, the dollars used for these systems are unavailable for other uses.

Wheat straw can be used as a soil amendment, an animal feed, or for other uses, such as, a feedstock for the production of paper or pharmaceuticals. Other agriculture crops (sorghum, corn, etc.) have a significant benefit as an animal feed. Feedlot manure has value as a soil amendment. At present municipal refuse and sewage sludge are not used and, in fact, present disposal problems.

Hence, all energy options involve compromises. Tough decisions must be made by energy suppliers and consumers!

II. The Pratt System Options

Figure 1 is a schematic of the various options which were considered in this feasibility study.

Study Conclusions

1. Wheat straw and other crop residues as well as muncipal refuse and feedlot manure can be used effectively to replace fossil fuels in the generation of electricity. Wheat straw was measured to have an energy content of about 7000 Btu per pound with about 7% moisture.

2. There is enough wheat straw around the city of Pratt, Kansas to provide for partial replacement of fossil fuels. We recommend a boiler designed to operate with 80% coal and 20% wheat straw, on a Btu basis.

3. The existing steam turbines and generators can be used with only a new furnace/boiler system required. This system would cost approximately $5,000,000.

4. The cost of wheat straw (for field operations and transportation to the boiler) is estimated from field tests to range between $25 to $35 per ton for large round bales and stacks.

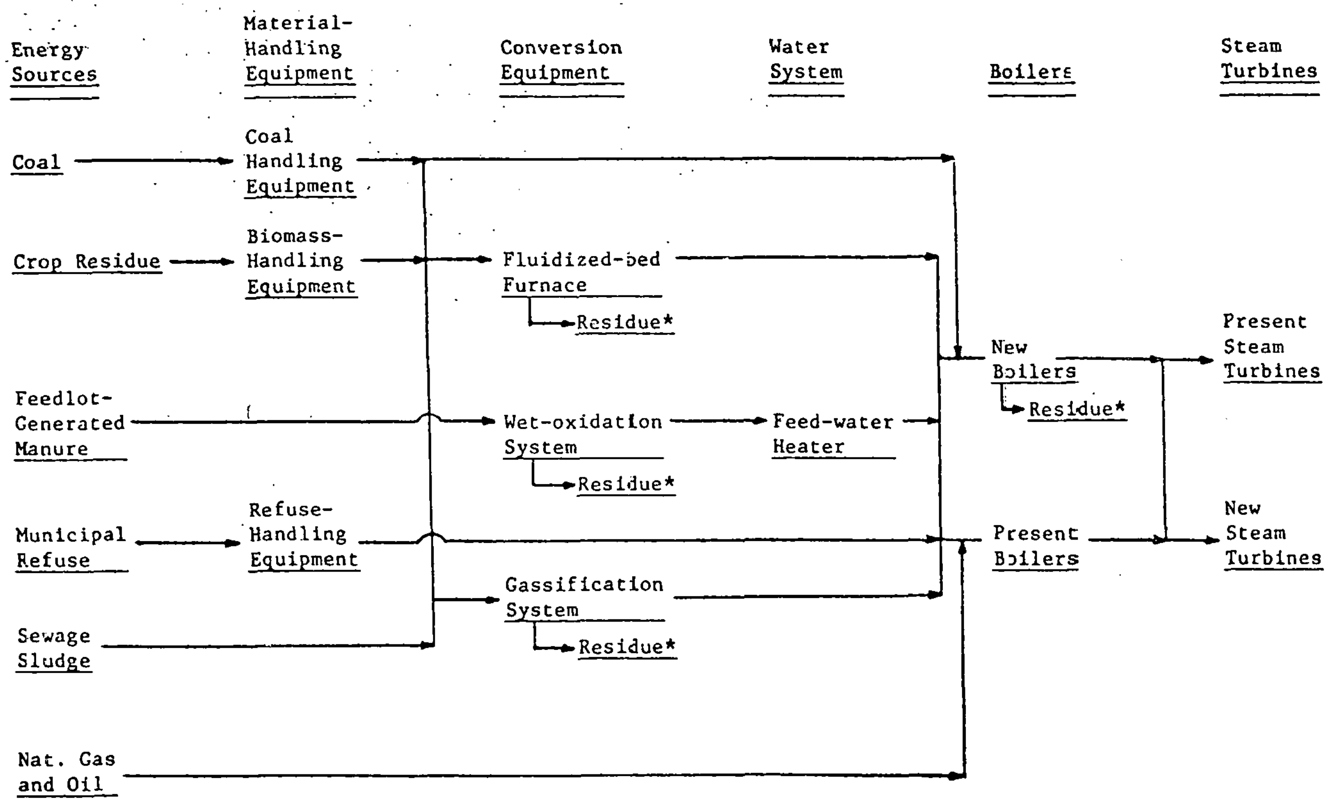
5. The nutrient value of the wheat straw is only about 2% of the energy available in the wheat straw.

6. The wheat straw can be removed from the fields, prescriptively, to minimize the impact of wind erosion. We recommend that all fields be modeled and that the model be used to indicate how much wheat straw can be removed before wind erosion becomes of overriding concern.

7. The results of a survey of area farmers indicated many (62% of those returning their questionnaires) were unwilling to sell their wheat straw residue. We feel the results are questionable and recommend a more comprehensive and detailed survey be conducted.

8. Production of biogas (with an energy content of about 170 Btu/scf) through the gasification of feedlot manure or crop residue is technically feasible. A 20 MW electric generating plant based on manure feed to produce biogas was the most economically attractive gasification system for Pratt. This required feedlot manure to be available from an area within a 40 mile radius of Pratt. The capital costs for this system were estimated to be about $12,000,000.

9. The wet oxidation of feedlot manure is technically feasible for preheating boiler feed water, but the energy obtained from this process is not cheap. Our analysis shows that the total capital cost would be about $6,000,000 and the equivalent cost of energy (with a load factor of 50% for the Pratt system) would be about $5.50 per million Btu.



*Residue must be disposed of, e.g., plowed back into the crop fields.

Figure 1. Schematic of the various options considered for the City of Pratt.

III. Recommended System for Pratt

Options Rejected

While technically feasible, the manure/residue gasification system, the wet oxidation boiler water preheat system, as well as direct combustion of municipal refuse and sewage sludge were too expensive. Hence, these processes were not recommended for commercialization at Pratt.

Wheat Straw Availability

Critical to the practicality of the use of wheat straw as a replacement boiler fuel is the availability of wheat straw and the ability to collect, consolidate, and deliver the wheat straw at an economically competitive price to the boiler site. There are about 4.67×10^9 pounds of removable wheat straw (based on 1970-1975 average crop production statistics) within the five counties near Pratt, i.e., Pratt, Stafford, Kingman, Kiowa, and Barber counties. This is about 3.27×10^{12} Btu per year or enough to supply about 2.5 times the electrical needs of the Pratt system (at an average connected load of 11 MWe and 25% thermal efficiency).

Survey of Farmers

The optimism of these calculations is dimmed somewhat by survey results which indicated only about 38% of the area farmers would sell their wheat straw for use as a boiler fuel. While these farmers could provide nearly all the energy needs (about 95% of the required 1.32×10^{12} Btu per year), we feel that only a portion of this material will be needed for the system we recommend (one fired with 80% coal and 20% wheat straw, by Btu content). These results notwithstanding we feel from comments made by area people, the use of wheat straw as a boiler fuel (and for other possible energy needs) will be more successfully received then the survey predicts. The results are probably more indicative of our naiveté in surveying farmers than their reticence to sell surplus wheat straw.

Environmental Impact of Wheat Straw Removal

There will be slight environmental effects involved in the removal of the wheat straw from the land. We recommend a prescriptive approach to its removal, i.e., only the amount should be removed as can be justified based on the accepted wind erosion model of the Soil Conservation Service. This model includes the following variables: soil erodibility, soil roughness, climatic factors, unsheltered distances, and soil vegetative cover. Farmers in the Pratt area practice several wheat farming techniques. Of these methods, first year harvesting followed by second year summer fallowing will probably not allow residue removal; depending on soil type and land management techniques (tillage methods, principally) as much as one third of the residue can be removed with a minimum of soil loss to wind erosion for other wheat farming methods. We definitely recommend that great care be exercized in contracting for and removal of residue. Farmers who view their surplus wheat straw as a new cash crop should work cooperatively with Pratt city officials and soil conservationists to develop a removal prescription and land management system to protect their land.

Nutrient Removal and Net Energy Balances

The subjects of nutrient removal and net energy balances were also addressed as environment concerns. We estimate one thousand pounds of wheat straw contains about seven pounds of nitrogen, one and two thirds pounds of phosphate, and twenty two and a half pounds of potash. When the straw is burned most of the nitrogen is returned to the atmosphere to course the nitrogen cycle again. A small amount of the phosphate is destroyed; the remainder of the phosphate as well as the potash remain in the ash and can be returned to the land. We estimate the nitrogen can be replaced in the soil by anhydrous ammonia using about 2.3% of the energy available in the removed wheat straw, and this can be done for about $0.66 per acre. We estimate for all energy inputs compared to the energy available from the removed straw that a gain of a factor of about 19 is accomplished, i.e., for each unit of energy used to harvest, collect, and transport the wheat straw to a boiler about 19 units of thermal energy are released.

Costs of Wheat Straw

To determine the costs involved in harvesting, consolidating, and transporting the wheat straw to the boiler, we conducted two series of actual field tests, in the summers of 1975 and 1976. In these tests three consolidation methods were tested on wheat straw which was windrowed by a slightly modified combine harvester. The modification consisted only of altering the spread of the wheat straw, which was processed through the combine (about 15%-33% of the total wheat stubble), into windrows instead of the normal uniform pattern. We collected about 56 tons of this processed wheat straw from about 108 acres by rectangular and large round bales as well as the large stack process.

Some difficulty was experienced in the collection phase due to heavy rains and high winds. Our experience indicates 0.442, 0.506, and 0.647 man-hours per ton of wheat straw are required for consolidation and stacking by the fields' edge for the stacks, round bales, and rectangular bales, respectively. Each of the consolidation methods has disadvantages: 1) stacks are low density, require experience in consolidation to prevent stack break-up, and special equipment is needed to move the stacks to the field's edge; 2) rectangular bales required special bale placement for transport to the field's edge and off-setting the bales to the ground requires a special technique; 3) round baling equipment experiences frequent maintenance problems and special equipment is needed to transport the bales to the field's edge.

In the cost analysis we assumed all straw would be collected within a three week period near harvest time and was stored near the field's edge until needed at the boiler. The total depreciation of the equipment was charged against the straw collection. The consolidation and transport to the field's edge ranged from about $17 per ton for the stacks, $29 per ton for the round bales, and $31.50 per ton for the rectangular bales. For the stacks and round bales and transporting 10 miles to 40 miles (from field's edge to boiler) we estimated the delivered cost of the wheat straw at about $25 per ton ($1.80 per million Btu), to about $35 per ton ($2.50 per million Btu), exclusive of any payments to the farmer for the straw. We consider a 40 mile range to be a maximum distance to remain competitive with low-sulfur, high-Btu delivered coal (a price of about $35 per ton has been estimated for the coal).

Wheat Straw Storage

There were some weathering problems; however, most of the collected straw withstood six to twelve months of field-edge storage. Both round and rectangular bales are not as susceptible to weathering as are the stacks. We need energy content data as a function of weathering conditions and time of storage. In most instances we feel farmers will require a storage fee as well as a payment for the straw.

Caution about Estimated Costs

Finally, we feel the costs which we estimated are probably somewhat high because we paid custom rates and dealt in small acreages. Also some of the operators were not as experienced as desired. We feel Pratt officials could lower these costs by proper contracts or ownership and operation of the consolidation and transportation system.

Combustion Properties of Wheat Straw

In our tests, wheat straw was measured to contain about 7000 Btu per pound at a moisture content of about 7%. We were unable to perform a proximate analysis, but we feel wheat straw is quite low (less than 5%) in ash. Sulfur emissions as well as nitrogen oxides should present almost insignificant problems. The method of combustion of wheat straw is apparently quite different from that of coal. Coal burns slowly via out-gassing, surface combustion; wheat straw appears to spontaneously ignite with little out-gassing.

Furnace/Boiler System Options

We investigated two principal furnace/boiler systems: 1) a fluidized-bed combustion system and 2) a stoker/over-firing system. Although we conducted combustion tests in a fluidized-bed system in Idaho, we feel these systems will be unavailable commercially in sizes needed for Pratt in the near future. Therefore we recommend a stoker/over-firing system which will use coal as the principal fuel (80% on a Btu basis) with wheat straw suspension-fired over the coal bed after being entered into the furnace pnuematically. We estimate an installed cost for this stoker system (35 MWe capacity) exclusive of steam turbine and generator to be approximately $5,000,000.

IV. Conclusions

The use of biomass in the form of wheat straw and other agricultural residue and wastes such as cattle manure, sewage sludge, and municipal refuse can be used as replacement fuel for steam systems. We estimate the cost of wheat straw to be competitive with low-sulfur, high-Btu coal delivered to Pratt. There is enough wheat straw available around Pratt and the straw can be removed prescriptively from the land with minimal impact. Equipment is currently available to harvest, consolidate, and deliver the wheat straw to the boiler site. At this time Pratt officials are deliberating on the funding possibilities for the construction of this system.

For the future, we believe the furance/boiler will be able to be fueled totally with biomass. The wheat straw may have to be pelletized to reduce the volume and to increase its density. We believe analyses are needed to determine the feasibility of using the condenser heat for district hot water heating. A careful study is needed of the possibilities for blending high-sulfur coal with low-sulfur coal and wheat straw for boiler fuel. New varieties of wheat need to be developed which can produce high quality grains and larger quantities of removable biomass for energy sources. We see present efforts at developing cottonwood trees and other biomass crops on marginal land in Kansas as a very promising source of energy. Certainly solar and wind energy will eventually assume an important position as energy resources for Pratt citizens.

V. Acknowledgements

A. Ozarks Regional Commission

1. Forrest J. Robinson, Governor's Liaison Officer for Kansas
2. Rich Watson, Contract Monitor

B. City of Pratt

1. Arlyn Bradford, Superintendent for Electric Production
2. James R. Pearson, City Manager
3. C. L. (Hap) Eckhoff, City Clerk
4. Conard D. Gilham, Mayor

C. Kansas State University

1. L. T. Fan, Head Department of Chemical Engineering
2. W. P. Walawender, Associate Professor, Department of Chemical Engineering
3. P. K. Handa, Graduate Assistant, Department of Chemical Engineering
4. Hossein Ganjidoost, Graduate Assistant, Department of Chemical Engineering

D. University of Kansas

1. K. A. Bishop, Professor, Department of Chemical and Petroleum Engineering
2. H. F. Rosson, Professor, Department of Chemical and Petroleum Engineering
3. V. Ramanthan, Graduate Assistant, Department of Chemical and Petroleum Engineering

E. Energy Incorporated, Idaho Falls, Idaho

L. C. Cale, Senior Engineer

F. Combustion Power Co., Inc., Menlo Park, California

Dale R. Moody

G. Babcock and Wilcox Power Generation Group, Overland Park, Kansas

A Progress Report

Direct Combustion of Crop Residues in Boiler Furnaces

by

Wesley F. Buchele*

Summary:

Research was conducted on converting the energy value of cornstalks to useful forms of energy by burning cornstalks as a companion fuel with high-sulfur coal in boilers of electrical generating plants. The cornstalks were harvested in the fall of 1975 and burned during April 1976. The value of cornstalks was compared with that of coal; costs of collecting, transporting and processing were calculated.

Introduction:

Since the OPEC boycott of petroleum in the fall of 1973, the world has become acutely aware that:

1. The world petroleum supply (oil and natural gas) is finite.

2. The major portion of the world's petroleum supply is owned by foreign nations.

3. The continuous supply of petroleum is by no means assurred.

4. The petroleum (a petrochemical feed stock) was being wasted on low-priority uses such as:

   a. heating and cooling buildings,
   b. generating electricity,
   c. removing water from materials, and
   d. powering transport vehicles over land and water surfaces.

The effect of the United States Environmental Protection Agency regulations began to be felt in this country at approximately the same time:

1. Stack emissions of existing coal-burning furnaces could contain no more 3 lb. of sulfur per million BTU's of heat generated.

* Professor of Agricultural Engineering, Iowa State University, Ames, Iowa.

2. The "compliance coal" burned in new coal-burning furnaces that burn more than 250 million BTU per hour cannot release more than 1.2 lb. of sulfur per million BTU.

The results of these two EPA regulations were to reduce drastically the nation's reserve of usable coal and to shift the demand for coal from the eastern coal fields to the western coal fields.

To meet the first regulation, Iowa coal (4 to 6% sulfur) must be mixed with Wyoming coal (0.8% sulfur) to produce a burnable mixture in furnaces and boilers of existing electrical generating plants. Compliance coal, with less than 0.5% sulfur, is found mainly in the western coal fields, and even much of that coal must be run through a beneficiation plant to bring it into compliance with standards for new plants.

Since that fateful fall, effort has been expended on a wide front toward developing methods of utilizing renewable energy resources such as wind, solar and crop residues. Little effort, however, has been expended in reconsidering regulations passed in more idealistic times.

Buchele (1973) and Green (1975) calculated the quantity of crop residue biomass (that not harvested or that rejected by the combine harvester) and found that this material represented one of the major unused energy resources of the nation. The nation's farmers expend considerable time, money and energy burying this crop residue with a plow.

Buchele and Green reasoned that the crop residue containing 0.06% sulfur could be burned as a companion fuel with high-sulfur coal. This would make possible the use of residue grown near steam-generating furnaces and materially increase the quantity of coal that can be burned.

Buchele (1975) discusses the need to leave one ton of crop residue in the field distributed on the surface of the soil to protect the soil from wind and water erosion. The use of conservation-tillage systems, including planting crops on graded ridges, was recommended to protect the soil from energized fluids. He proposed that cornstalks, besides being used as fuel, be utilized as a chemical feed stock for the production of methanol, anhydrous ammonia and furfural, a source of cellulose for paper and wallboard production.

This report deals with the harvesting, loading, transporting, processing and burning of cornstalks in a steam-generation furnace of a municipal electric plant.

Utilization of Cornstalks by Farmers:

The above-average Corn Belt farmer produces about 120 bushels of corn and about 6000 lb. of plant parts (cornstalks) per acre. The grain-to-cornstalk ratio is about 0.53 to 0.47, respectively.

Today's farmer removes by grazing or harvesting for animal feed or bedding, about 10 percent of the cornstalks. The other 90 percent of cornstalks rejected by the combine are left in the field where they are processed by stalk choppers and eventually incorporated into the soil to varying degrees with primary tillage tools.

Research by Mannering and Meyer (1963), by Moldenhauer et al. (1971), by Laflen et al. (1977) and by Yazdanpanah (1976) and others has shown that, when 2200 Kg/ha (1 ton/acre) of crop residue is left on the surface of the soil, the soil losses by erosion will be kept within reasonable bounds.

If this residue-covered field (1100 Kg/ha) is farmed on a graded contour with a conservation-tillage system, the soil loss by water and wind erosion will be materially below the allowable loss limit of approximately 11,000 Kg/ha (5 tons/acre) prescribed by most soil conservation statutes of the various states of the union.

Research by Laflen et al. (1972) has shown that, of the soil carried by water into the impounded area located behind tile-outlet terraces, only 1/20 of the soil leaves the field with the water flowing out of the tile outlets. The other 19/20 of the soil settles and collects on the bottom of the terrace channel.

When graded rows with surface residue cover are farmed with a conservation-tillage system located on terrace-protected land, the loss of soil by erosion will be approximately 1/100 of that lost from fields farmed with a conventional plow-based tillage system.

Williams and Dönen (1960) studied the effect of incorporating crop residue and green manure into the soil on the infiltration rate of water. They found that low-nitrogen crop residues (barley, straw and cotton stalks) improve infiltration rate, while high-nitrogen green manure crops (Sudangrass) do not materially affect the infiltration rate over fallow (bare) soil.

Because of the need to control the loss of soil and water, Buchele (1975) presented the budget shown in Table 1 for using cornstalks on a Corn Belt farm.

Table 1

Budget for Utilization of Cornstalks

on an Iowa Farm

Total Production		6000 lb/acre
Left on surface for controlling erosion	2000 lb/acre	
Utilized around the farmstead	1000 lb/acre	
Total cornstalks used on farm	3000 lb/acre	
Cornstalks available for on or off farm use		3000 lb/acre

This table shows that sufficient biomass is grown as supporting plant structure with the corn crop to control loss of water and soil from the land, dry the grain, heat the farm home, feed and bed the livestock, etc. Approximately 3,000 lb./acre still remain for use in the generation of electricity and the manufacture of methanol and (or) anhydrous ammonia.

The crop residue uniformly distributed on the surface of the soil protects the land in the following ways:

1. Prevents wind and water erosion.
2. Reduces evaporation of water from soil.
3. Reduces temperature of soil.
4. Increases water infiltration into soil.
5. Increases the quantity of carbonaceous matter in soil.
6. Provides a source of fertilizer.
7. Provides energy sources for soil microorganisms.

It also provides food and homes for insects for insects and rodents and is a host for plant diseases.

The crop residue when plowed under:

1. Increases the quantity of carbonaceous matter in soil.
2. Provides a source of fertilizer.
3. Provides an energy source for soil microorganisms.

The farmer may utilize cornstalks in some of the following ways around the farmstead.

1. Feeding livestock.

2. Bedding livestock.

3. Fuel for corn dryer.

4. Heating farm homes.

5. Heating other farm buildings.

As the energy shortage increases, the farmer may install equipment for converting cornstalks to other forms of energy or products needed on the farm.

1. Generate electricity.

2. Generate methane gas from wet organic matter.

3. Generate producer gas from dry organic matter.

4. Manufacture of methanol.

5. Manufacture of anhydrous ammonia.

The cornstalks not needed for preventing soil erosion or on the farm are available for off-farm sale to commercial interests for:

1. Generating electricity.

2. Manufacture of methanol.

3. Manufacture of anhydrous ammonia.

4. Production of furfural.

5. Production of paper.

6. Production of hardboard.

Economic Aspects of Harvesting Cornstalks:

It is expected that farmers harvesting a portion of the cornstalks will use a conservation-tillage system of corn production. They will record the savings in Table 2 by eliminating the cornstalk disposal operation normally done ahead of plowing.

Table 2

Savings From Eliminating

Cornstalks Disposal Operations

Cornstalks Disposal Operation	Cost $/acre
Chopping stalks	$ 5.89
Disking stalks	2.84
Plowing stalks under	8.09
Total cost for disposing of cornstalks	$16.82
Differential cost of till planting over conventional planting operation	1.00
Total savings from eliminating the disposal operation	$15.82

The cost of harvesting and hauling 1½ tons of cornstalks is shown in Table 3. This is based on the farmer using a 2½-ton stack wagon, harvesting 450 tons per year from 300 acres of land, with an expected life of 8 years.

The ashes remaining after combustion of cornstalks contain P, K and C and can be returned to the land with bulk fertilizer spreaders. The nitrogen unfortunately is oxidized and lost with the flue gasses.

Table 4 is a recalculation based on returning the P, K and C to the land.

Table 3

Cost of Harvesting and Transporting of

Cornstalks and Replacement Value of Fertilizer

	$/acre
Cost of harvesting 1½ tons of cornstalks @ $10.70/ton	$19.05
Transportation of 1½ tons @ $2.00/ton	3.00
Replace fertilizer in 1½ tons of cornstalks	
N 0.01 · 2000 · 20¢/lb. · 1.5	6.00
P (0.003 · 2000 · 18¢/lb. · 1.5)	1.62
K (0.014 · 2000 · 8¢/lb. · 1.5)	3.36
	$33.03

The cost of harvesting, replacing the fertilizer and transporting the cornstalks from 1 acre ($33.03/acre) over the cost of tillage ($15.82) is $17.21/acre or $11.47/ton.

Table 4

Cost of Harvesting, Transporting of Cornstalks

and Spreading Ashes and Additional N on the Land

	$/acre
Cost of harvesting 1½ tons of cornstalks @ $10.70/ton	$19.05
Transportation of 1½ tons of cornstalks @ $2.00/ton	3.00
Replace fertilizers in 1½ tons of cornstalks	
N (0.01 · 2000 · 20¢/lb. · 1.5)	6.00
Extra cost of handling and spreading N and ash (1.00/acre)	1.00
	$29.05

The cost of harvesting, replacing nitrogen and ash and transportating the cornstalks from 1 acre $29.05 over the cost of tillage $15.82 is $13.23 per acre or $8.82 per ton.

Table 4 shows that any selling price received by the farmer over $9.46/ton ($6.82/ton) is a clear profit.

What is the Value of the Cornstalk?

In some areas of the country, cornstalk stacks sell for half the price of alfalfa hay. One farmer paid $50.00 for 3 tons of stalks setting in the field. Another farmer paid $75.00 for 3 tons delivered, for cattle feed. The value of cornstalk stacks fluctuates widely, depending on the availability and need for hay.

The value of cornstalks, as a direct replacement for coal,, can be calculated based on the cost of coal. But the extra costs of processing and feeding cornstalks into the furnaces are at best only estimates.

Wyoming coal cost $22.65/ton delivered to Ames, Iowa, on Jan. 1, 1976, and had a heat content of 9,561BTU/lb.The moisture content was about 40%.

$$\frac{\$22.65}{9{,}561 \text{ BTU} \cdot 2000 \text{ lb.}} = \$1.18/10^6 \text{ BTU}$$

Cornstalks (1.5 tons/acre) are available for biomass utilization and have a heat content of about 6,000 BTU/lb. (moisture content is 22%).

$$2000 \cdot 1.5 \cdot 6000 \cdot \$1.18 \cdot 10^{-6} = \$21.24/\text{acre} = \$14.16/\text{ton}.$$

But, because of the low sulfur content found in cornstalks, 0.15% (Morrison, 1954) to 0.06% (Green, 1975, Private correspondence), they could be burned as a companion fuel with 5.2% sulfur Iowa coal, costing $17.15 delivered in Ames, with a heat content of 9,895 BTU/lb.

$$\frac{\$17.15}{9{,}895 \text{ BTU} \cdot 2000 \text{ lb.}} = \$0.87/10^6 \text{ BTU}$$

The quantity of heat and sulfur for 1 ton 5.2% sulfur content Iowa coal is:

$$9{,}895 \cdot 2000 = 19.8 \times 10^6 \text{ BTU of heat and 104 lb. of sulfur.}$$

To meet EPA Emission Standards (3 lb. of sulfur per 10^6 BTU), the heat content of the mixture of cornstalk and coal must be greater than:

$$\frac{1{,}000{,}000 \text{ BTU}}{3 \text{ lb.}} \cdot 104 \text{ lb.} = 34.7 \times 10^6 \text{ BTU}$$

The quantity of cornstalk that must be added to a ton of coal is calculated as follows:

BTU's of heat that must come from cornstalks:

$$34.7 \times 10^6 - 19.8 \times 10^6 = 14.9 \times 10^6 \text{ BTU}$$

Weight of cornstalks added to each ton of coal:

$$\frac{14.9 \times 10^6 \text{ BTU}}{2000 \text{ lb.} \cdot 6000 \text{ BTU/lb.}} = 2{,}483 \text{ lb.}$$

The equivalent value of Wyoming coal based on heat content:

$$\$34.7 \times 10^6 \cdot 1.18 = \$41.10$$

The price that can be paid less processing cost for the 2,483 lb. of cornstalks that must be burned with 1 ton of Iowa coal is:

$$\$41.10 - \$17.15 = \$23.95$$

The premium price per ton that can be paid for cornstalks is:

$$\frac{\$23.95 \cdot 2000 \text{ lb./ton}}{2{,}483 \text{ lb.}} = \$19.29\text{/ton of cornstalks}$$

If it costs \$5.00/ton to handle and process cornstalks at the generating plant, then the utility company can afford to pay \$19.29 - \$5.00 = \$14.29/ton of cornstalks. The price received by farmers and net cost of harvesting and transporting the cornstalks are as shown:

Table 5

How Much Profit Does the Farmer Make?

Maximum price utilities can pay for cornstalks	\$14.29 per ton
Net cost of harvesting cornstalks	8.82 per ton
Net profit to farmer	\$5.47 per ton

On an acre basis, the farmer will receive a net profit of \$5.47 · 1.5 = \$8.21 per acre.

<u>The Burning of Cornstalks as a Companion Fuel With Coal in the Ames Solid Waste Plant:</u>

The purpose of these tests was to obtain experience and data on the utilization of cornstalks as a companion fuel in a municipal solid waste recovery system in cooperation with the municipal government of Ames, Iowa. The Ames Solid Waste Plant began operation on Nov. 1, 1975.

The following factors were studied:

1. Harvesting of cornstalks.
2. Storage of cornstalk stacks.
3. Loading of cornstalk stacks in flatbed trucks.
4. Transporting of cornstalk stacks.
5. Unloading of cornstalk stacks.
6. Processing of cornstalk stacks.
7. Burning of cornstalks.
8. Management of the agricultural machinery associated with these tasks.
9. Physical properties of processed cornstalks.

Harvesting of Cornstalks:

The cornstalks were harvested with a John Deere model 30 stack wagon (Figure 1) between 10 and 20 days after the grain was combined. The stalks were harvested from privately owned farms and university-owned farms.

As now practiced (1977), cornstalks harvesting starts after the crop residue (plant parts rejected by the combine) is dropped on the ground and has dried to approximately 25% moisture content. Depending on the weather and original moisture content of the stalks, this operation could start 0 to 30 days or more after grain harvest. The stacks used in these tests were harvested in Nov. 1975 and were burned in Apr. 1976.

The cost of harvesting cornstalks with a stack wagon is dependent mainly on stack wagon size, expected life of equipment and number of stacks harvested.

The cost of harvest includes dumping the stacks at the side of the field where they can be easily retrieved later.

Storage of Cornstalks:

The stacks were placed along the edge of the field located near a road and on both sides of culverts that bridge the ditch between the road and the field. Other stacks were located along roads in the field. In all instances, the stacks were placed on high ground. This was done so that they could be easily reloaded and hauled from the field without rutting the field during wet weather or when snow covered the ground.

Because the fields were not in production, no cost was assessed against the storage of the bales. If the cornstalk field were pastured after the cornstalks were harvested, a fencing cost could be assessed against the stack or bales.

The cornstalk stacks seemed in good condition (Figure 3). Little rain or snow had fallen between the time they were made in Nov. 1975 and Apr. 16, 1976. Some cornstalks were blown off the stacks during high winds and accumulated around the base of the stacks. The cornstalk stacks for Test 1 were dry and off good quality.

During the time between Test 1 and Test 2, 6-8 inches of rain fell on the cornstalk stacks (Apr. 15 to Apr. 22).

The stacks at the time they were loaded for Test 2 on Apr. 27 and 28 were wet on the top, windward side and base of stack. The rest of the stack was of low moisture content.

Test 1:

This test was conducted on Apr. 5 and 6, 1976, to determine the magnitude of the shredability and associated dust problems of cornstalks when processed in the Ames Solid Waste Plant and to evaluate methods of loading and transporting cornstalks.

The following equipment was used during Test 1 to load and transport the cornstalks to the Ames Solid Waste Plant:

1. Chainbed stack mover.

2. Flatbed dump truck, 2½ ton.

A chainbed stack mover designed for moving corn stacks and giant round bales was used to load the stacks onto the flatbed dump truck in Test 1 on Apr. 5. The stack mover was backed to the first stack, and the stack was loaded onto the stack mover by operation the chains in the forward direction as the stack mover moved rearward and under the stack.

When the stack mover was loaded, the stack mover bed was adjusted to the level of the truck bed (the truck bed could also be adjusted to improve the transfer), and the chains of the stack wagon again operated in a forward direction to load the truck.

The stack mover was then backed to the second stack, and the second stack loaded. During this operation, which was tedious, several chains broke. The stacks were hauled to the Ames Solid Waste Plant, located about 6 miles east of the field, at 9 a.m., Apr. 6, 1976. The cornstalk stacks on the truck were dumped on the loading floor by raising the dump bed of the truck. Because two chains of the stack mover were broken, the John Deere Industrial Loader located at the solid waste plant was used to push the cornstalk stacks off the stack mover.

The industrial loader was used to push the cornstalks into the solid waste plant feeder system. The feeder belt fed the cornstalks to the primary shredder at the rate of 50 tons per hour.

No problems were encountered with shredding the cornstalks, and a dust problem simply did not develop. The shredded cornstalks were delivered by belt and air transport to the Atlas bin. They were uniformly metered from the Atlas bin into the air-conveying system, which transported the material into the coal-fired, traveling grate, steam-generating furnace (Unit Number 5). The cornstalks were fed as a companion fuel with 3% sulfur content coal into the furnace at the rate of 4 parts coal to 1 part cornstalks (by weight). The capacity rating of the furnace was 500 tons of coal per day. Because there was solid waste on the dumping floor and in the Atlas bin, a mixture of ground stalks and solid waste was delivered to the boiler furnace for burning.

Test 2:

Because no difficulty was encountered with the processing, transporting, metering or burning of the cornstalks, the Solid Waste Plant manager agreed to receive cornstalks on Tuesday, Apr. 13, 1976, beginning at 4:00 p.m. But information was received on the morning of Apr. 13 not to deliver cornstalks because the Atlas bin was nearly full of solid waste. The furnace burning solid waste had been shut down for repairs. We agreed to start delivering cornstalks at 4:00 p.m. on Apr. 20, but rain began falling on Friday, Apr. 15 and continued for nearly 1 week.

On Monday, Apr. 26, after about 4 drying days, the ground seemed dry enough to support the trucks and loading equipment. The following equipment was used during Test 2 to load and transport the cornstalks to the Ames Solid Waste Plant:

1. Forklift truck (capacity of 6,000 lb.)(Figure 4).

2. Four-tine fork from a B&C stack mover.

3. Industrial Ford Tractor equipped with a front end loader and a backhoe.

4. An International Tractor equipped with a front loader (Figure 5).

5. Five flatbed trucks $2\frac{1}{2}$ tons (4 trucks were equipped with flat-dump beds and one had a nondumping flatbed. The load was pushed off the nondumping flatbed truck at the Solid Waste Plant with the industrial loader.

The stacks were loaded onto the trucks (Figure 4) and hauled to the Solid Waste Plant on Apr. 27 and 28, 1976, starting at 4:00 p.m. on the 27th and finishing at 5:30 p.m. on the 28th.

Because the planting season was at hand, the cornstalks were moved as quickly as possible to avoid delay of field work after the rain even though the fields were quite wet.

Because of the wet ground, a special method of loading the stalks onto the truck was used. An International Tractor, equipped with the front end loader, was used to push the cornstalks (which had blown off the top of the stacks and accumulated on the ground between the stacks) away from the base of the stacks so that the tines of the forklift could be placed on the ground next to the stacks. After the cornstalk trash was removed, the fork lift, equipped with B&C fork was driven to the stack. The forks were lowered, and the fork-tines (using the tractive power of the forklift truck, plus the tractive power of a Ford Industrial Tractor equipped with the front end loader and backhoe) were shoved into the stack of cornstalks. The tilt of the tines of the fork was important, if tilted downward too much, they were shoved into the ground. If tilted upward too much, the tines ran upward into the stacks and a part of the stack was left on the ground when the stack was lifted.

The forklift truck was stabilized, preventing it from rearing over frontward while picking up the stacks, by placing the front end loader of the Ford tractor on a plate attached to the rear of the forklift. Downward pressure was placed on the rear of the forklift by the use of the hydraulic cylinders of the front end loader, and then the backhoe itself was pressed against the ground to place the full weight of the tractor on the forklift. After the stacks were lifted by the forklift, the $2\frac{1}{2}$ ton truck was backed under the lifted stack of the cornstalks, and the stack was lowered onto the bed of the truck. By using the tractive power of the forklift truck and the tractive power of the Ford tractor, the fork-tines were pulled from under the cornstalk stacks.

At various times, the corn stacks would stick to the fork-tines, and the stack would be pulled off the truck bed with the fork-tines when retracted. The fork then would have to be raised and the fork lift truck shoved forward again to place the stack back on the tractor. Two fence posts (approximately 8 ft. long and 8 in. in diameter) were placed on the bed under the stack and between the tines of the fork. The cornstalk stacks again were lowered onto the bed of the truck, and the fork-tines pulled from under the stack. The posts either were retrieved by attaching a chain to the post and pulling them from underneath the cornstalk stack while the truck was still in the field or were retrieved as the load was dumped from the truck at the solid waste plant. In this instance, as the bed was tilted, the load of stalks would slide off. The posts would roll as the load slid off and drop on the floor at the rear of the truck bed. They were quickly removed before the load of stalks fell on the posts.

If the load was not centered on the truck bed, the front end loader was placed against the stack, and the tractor was used to push the load into position. If the truck became mired in the mud of the field, the industrial tractor equipped with a front end loader and backhoe was used to push the truck (Figure 5).

The time of loading when no problems were encountered was approximately 5 min. It took much longer to load when the cornstalk stacks stuck to the fork-tines and were pulled from the truck when backing up. Once, it took almost 1 hour to load one stack on the truck.

Where the ground was too soft for truck traffic, the forklift truck was pushed under the corn stacks; then the tractor, equipped with front end loaders and backhoe, was used to pull the forklift truck with the corn stacks raised slightly off the ground to higher and dryer ground until the truck could back underneath the load and have the load dropped on the bed of the truck.

One time, the truck, which was turning around in the field after loading and going rapidly to avoid becoming stuck in the soft ground lost the corn stack in the turn; it was thrown off the bed by centrifugal forces.

The cornstalk stacks have to be of good quality; the stack must stick together to be loaded and transported. In one instance in which the cornstalk stack was not properly tied together during the formation of the stack, the top portion of the stack sheared from the stack and slipped off the truck after loading.

<u>Transporting of Cornstalks</u>:

Once loaded, the trucks carrying the cornstalk stacks were driven on the highways at approximately 25-30 mph. There was little loss of cornstalks during transporting (Figure 6). We believe that weathering and the 6-8 in. of rain, that fell during the preceding week were major factors in keeping the cornstalks stuck together so that they resisted being blown away while being transported.

Unloading the Cornstalks at the Solid Waste Plant:

The floor of the solid waste plant had been cleared of solid waste by 4:00 p.m. Apr. 27, 1976. The plant began receiving cornstalks at that time and continued to receive cornstalks until about 10:30 p.m. The loading equipment was moved at 10:00 p.m. from the west field to the north field and loaded with cornstalks for morning delivery.

The trucks hauling the cornstalks were driven into the solid waste plant (Figure 7), stopped at the scales and were weighed, were driven forward again and backed up the unloading spot designated by the solid waste plant floor manager. The truck bed was then hydraulically raised, and as the load (Figure 8) slid off the rear end of the truck, the truck moved forward during dumping to complete the dumping of the load of cornstalks. If there were any posts located underneath the cornstalk stacks, they were retrieved at that time and thrown onto the bed of the truck after it was leveled. The unloading time was approximately 2 min. when the solid waste plant was receiving only stacks.

Cornstalk stack hauling began again at 5:30 a.m. on Apr. 28. When the plant began receiving solid waste at 8:00 a.m., Apr. 28, the cornstalk stacks were kept separate from the solid waste. The cornstalk stacks were dropped at the rear of the building, and the solid waste was dropped at the front of the building. An open road was maintained from the front of the buildings, around the solid waste pile to the cornstalk stacks. Unloading time under these conditions was approximately 12 min.

The front loader was used to push the cornstalk stacks into a pile at the rear of the solid waste plant and to feed the stacks into the feeder system.

The solid waste plant began processing cornstalks at 6:00 a.m. on Apr. 28, 1976. The shredders clogged with wet cornstalks around 7:30 a.m., and the floor manager of the solid waste plant told the truck drivers to stop delivery of cornstalk stacks. The last truck was dumped at 8:30 a.m.

When the solid waste plant stopped receiving cornstalk stacks at 8:30 a.m., the trucks, forklift and tractors were transported back to the Agricultural Engineering Farm. After the shredder was unclogged, the solid waste plant manager agreed to continue receiving cornstalks at 10:00 a.m. It took an hour and a half to reassemble the loading crew. Delivery of the cornstalk stacks to the solid waste plant began again at 11:30 a.m. Cornstalks continued to be delivered from the north field until approximately 2:00 p.m. All the stacks that could be retrieved from the field had been oaded. The loading equipment was moved to the south field, and delivery was continued from 2:30 p.m. until 5:30 p.m. at which time all the stacks that could be retrieved from this field were loaded. The cornstalk stacks hauling operation was terminated. In all, approximately 50 cornstalk stacks were hauled in a 20-hr. period.

The following is a summary of the transporting schedule:

1. Loading of corn stacks began approximately 2:00 p.m. Apr. 27, 1976, in the west field.

2. Cornstalk stacks were received at the solid waste plant at 4:00 p.m. Apr. 27, 1976.

3. Cornstalk stacks receiving was closed at 10:30 p.m. Apr. 27, 1976.

4. Cornstalk stacks were received from 5:30 a.m. until 8:30 a.m. Apr. 28, 1976.

5. Cornstalks were embargoed from 8:30 a.m. to 11:30 a.m. Apr. 28, 1976.

6. Cornstalks were received from 11:30 a.m. to 5:30 p.m. Apr. 28, 1976.

Management of Machinery:

Capacity and work efficiency were calculated from the data collected during the test.

Field transport speed	5 mph
Average highway transport speeds	30 mph
Distance between field and processing plant	7½ miles
Total transport distance	15 miles
Time loading	5 minutes
Time of unloading	4 minutes
Transport time 15 miles at 30 mph	30 minutes
loading	6 minutes
unloading	4 minutes
	40 minutes

$$\text{Tons per hour} = \frac{\text{5 trucks x 2 tons x 60 min.}}{\text{40 min.}} = \text{15 tons/hr}$$

4:00 to 10:30 p.m.	6½ hours
5:30 to 8:30 a.m.	3 hours
11:30 to 1:30 p.m.	2 hours
2:30 to 5:30 p.m.	3 hours
	14.5 hours

The truck actually delivered 100 tons to the solid waste plant.

$$\text{Work efficiency} = \frac{\text{100 tons}}{15 \cdot \text{14.5 tons}} = 46\%$$

The work efficiency was low because of the wet soil conditions at the time the test was conducted.

Shredding of Cornstalks:

The cornstalks were wet, and the rate of feeding of cornstalks into the shredder was 15 to 20 tons/hr. The feeder to the air classifier stopped up twice during the day, and the air classifier stopped up approximately 10 times because of the wetness of the stalks and overfeeding of the equipment. Discussions with the Ames personnel indicated that, under the wet conditions, the wet portion of the cornstalk stacks handled about like livestock manure and would have to be fed at the rate manure is fed into the hammermill.

It is believed that the cornstalks were about as wet as they would ever be because they were received at the solid waste plant almost immediately after more than 6 in. of rain had fallen on the stacks. It is believed that the cornstalks would have dried out and would have been in better condition had delivery been delayed to the solid waste plant.

It is, however, fortunate that we were able to conduct the test under some of the most difficult conditions that will be encountered during the handling and hauling of cornstalks. The wetness of the cornstalk stacks, as indicated earlier, might be a desirable feature as far as preventing loss of trash while being transported on the highways, but was an undesirable feature during the loading of the cornstalk stacks. The stacks were much heavier than they would have otherwise been. They also slowed the feeding of the cornstalks into the shredder at the solid waste plant.

Burning of the Cornstalks:

The cornstalks, after being shredded, were blown by air transport to the Atlas bin of the solid waste plant. They entered the top and fell on the cone-shaped pile of solid waste in the Atlas bin. The bottom unloading system removed the cornstalks and solid waste already in the bin and delivered them in a uniform flow to the traveling-grate boiler of the Ames plant. The cornstalks were fed to the traveling-grate boiler at the rate of 5 tons/hr.

Physical Characteristics of Cornstalks:

Moisture content of the cornstalks was sampled from stacks in the field. The samples were taken from the south side of the stack and 3 ft. above the ground.

Distance from Side of Stacks	Moisture Content
0 to 2 in.	48%
2 to 4 in.	39%
4 to 6 in.	27%

The physical properties of the processed cornstalks being delivered from the Atlas bin on Apr. 28, 1976, (Test 2) were determined by the power plant personnel as follows:

Moisture content of processed cornstalks	30%
Weight per cubic foot	4½ lb.
Heat content of wet material	4500 BTU/lb.
Heat content of dry material	6500 BTU/lb.

Observations of the Ames Power Plant Personnel:

Observations made by the power plant personnel indicated that the cornstalks burned well, and they believed there would be no problem with using cornstalks as a fuel in their furnaces. Observations of the traveling-grate indicated that all the organic material being blown into the furnace was burned in the furnace. No problems were encountered from the stoppages in the air-transport delivery system, the divider system or the nozzle system of the solid waste fuel-delivery system.

Analysis of Results and Conclusions:

These tests showed that there are no equipment restraints that would prevent cornstalks from becoming a major renewable source in the Midwest.

Cornstalks can be harvested, stored in the open, transported, processed and burned with existing equipment. As this energy source is utilized, equipment will be automatically developed by the farm machinery companies for improving the work efficiency of the loading and transporting phase of the operation.

References:

Buchele, Wesley F. (1973). Grain and energy produced in 1972. Unpublished data. Agricultural Engineering Department, Iowa State University.

Buchele, Wesley F. (1975). Harvesting and utilization of cornstalks from Iowa farms. Agricultural Engineering Department, Iowa State University.

Buchele, Wesley F. (1976). Research in developing more efficient harvesting machines and utilization of crop residue. Transactions of the ASAE, 19-809-811.

Green, Farno L. (1975). Energy potential from agricultural field residues. Presented before the American Nuclear Society, New Orleans, 1975.

Green, Farno L. (1975). Private Correspondence. Warren, Michigan.

Laflen, John M., H. P. Johnson and R. C. Reeve (1972). Soil loss from tile-outlet terraces. Journal of Soil and Water Conservation, 27: 74-77.

Laflen, John M., J. L. Baker, R. O. Hartwig, W. F. Buchele and H. P. Johnson (1977). Soil and water loss from conservation tillage systems. Paper on press, ASAE.

Mannering, J. W. and L. D. Meyer (1963). The effect of various rates of surface mulch in infiltration and erosion. Soil Science Society of America Proceedings, 27: 84-86.

Moldenhauer, William C, W. G. Lovely, N. P. Swanson and H. D. Currence (1971). Effect of row grade and tillage system on soil and water losses. Journal of Soil and Water Conservation, 26: 193-195.

Morrison, Frank B. (1954). Feeds and feeding. The Morrison Publishing Company. Ithaca, New York.

Williams, W. A. and L. D. Donen (1960). Field infiltration studies with green manure and crop residue on irrigated soil. Soil Science Society of America Proceedings, 24: 56-61.

Yazdanpanah, Mohammad Sedegh (1976). Effect of surface shape, crop residue coverage and consecutive storms on soil erosion and water loss. Unpublished M.S. thesis. Iowa State Library, Ames, Iowa.

PANEL DISCUSSION OF SECOND DAY'S PROCEEDINGS

<u>CHAIRMAN</u>: Mr. Dwight Miller, Assistant Director
Northern Regional Laboratory
Agricultural Research Service, USDA

<u>PANEL MEMBERS</u>: Dr. William Duncan
Professor of Theoretical Crop Husbandry
University of Florida

Dr. Elmer Kiehl
Dean of the College of Agriculture
University of Missouri

Dr. Donald McPhee
Vice President of Kansas City Power and Light Company

<u>MR. MILLER</u>: As chairman I'm going to exercise my prerogative and just say a few things before we get into our discussions.

First of all, I would like to congratulate the speakers and this group as a whole because I practically have not heard the term "waste" used. This is one of my pet peeves, because I think we have byproducts and residues but they are no longer wastes. And Roscoe Ward started right out the first day very nicely setting the pace for this. Some of our things we used to call wastes are now things that may be vital resources.

I would like to say that not a week goes by but that I receive perhaps a dozen, maybe more, letters from all over the United States, in fact, all over the world asking about the production of alcohol by fermentation, primarily from cereal grains. And I must say that from some of these letters I have learned new names to call the Arabs, I have learned new names to call the industrialists. They speak very clearly. And what we may say in world ideas, a lot of our people in the United States do not share this. In other words, they say "these people blankety-blank so-and-so who are putting us in all of this, let's forget them, I don't care what the cost is, let's take anything that we can spare and let's make fuel out of it," and, of course, alcohol comes to the front.

One role that we have had at the Northern Regional Research Center has been to try to put it to these people in proper perspective as we know it. First of all we say that it has been shown that it is technically feasible to convert many of these materials and certainly cereal grains into ethyl alcohol. It is also technically feasible to use this alcohol, to some degree, at least, as an additive into our motor fuels and it works very fine. Unfortunately, if it's not economical to use alcohol as a fuel, then it's not going to be used.

And I would like to commend what the Andersons are doing, and what is being done in Nebraska in the gasohol research.

Nebraska is a unique state. It is an agricultural state, they have situations that certainly are not the same in Rhode Island, and therefore I am anxious to see how they come out and what they do in their whole setup.

Certainly we must look at various factors as we go along. I am shocked to see, as are many others, that when we ate our food today that for practical purposes 10 Btu of energy went into every Btu we consumed today. In general on the farm the best I have seen is that we are just about running one to one today from a production standpoint. We are putting about 1 Btu in for every Btu we are harvesting off. And by the time you take fertilizers and you get it onto the food table, the ratio comes out at about 10 to 1.

I would like to again emphasize that as we look at alcohol the byproducts are extremely important, particularly the distillers' grains. I believe there is a 34 cents credit for byproducts grain for each gallon of alcohol produced. Dr. Scheller suggested a larger byproduct credit. These byproducts are extremely vital materials. Why are they paying this much for it? Because of its important oil, protein, and other vitamins and minerals that are in this whole thing. Dr. Sheppard said in his talk that if the corn is degerminated then you can get the oil out of the germ and sell this oil. I want to point out that that most of the oil and protein in the corn is in that germ and this ends up in the distillers' grains. If it is not there you are not going to get the 34 cents a gallon credit for the byproducts.

I have been emphasizing that distressed grain or low quality grain may very well work just fine in Nebraska if there is enough of it. If the grain is moldy, because of the aflatoxin and mycolotoxins that are found in it, using the byproducts will be ruled out by the Food and Drug Administration. Until we know how to remove the aflatoxin and the mycolotoxins you are not going to be able to use the moldy grain. You can convert the starch that's in there to alcohol, but you cannot take this byproduct credit that is so vital.

Eight or nine years ago I was asked to bring together the alcohol from grain production picture. I presented this at the wheat utilization conference in Oakland, California. It opened Pandora's Box because it hit the papers, it hit the journals and everything else. I said it was technically feasible to produce alcohol from grain, it was all a case of economics. At that time, we had a tremendous surplus of grains and to a certain extent we are back to that right now.

We must not overlook as we are producing our crops that for every pound that we are harvesting, we are producing another pound or more. We have already put the energy in it, we have already used the land, and overall we must be sure that we make the best use of all of these materials.

I have implied by some of my talk certain criticism of some of the things that have been said today. I don't intend to do that. I just think that we need to be aware of exactly what the situation is and what it will be.

While we are talking about grain, I would like to ask Dr. Duncan to speak first, because he has also been involved in this study.

DR. DUNCAN: I would like to refer back to what Dale Moss said in his speech. We were starting out with the fact that the energy that produces this biomass comes from the sun. This is the whole story. And as I have listened to the presentations, I have gotten the idea that the whole business of production and where you produced it was sort of a magic combination of unexplained mysterious events. I would like to sort of rationalize a little picture about where biomass is produced and how much is produced and why one plant produces more than the other.

I was at Purdue with another agronomist on a beautiful day in Indiana with the blue sky and the sun shining and the temperature about, oh, 85 or 90 degrees. We went out and looked at some corn in about July and the corn leaves were a beautiful green. It was planted thick enough so you couldn't see the ground. My companion said, "Bill, this is a 6-bushel day." And what he meant by that was that under perfect conditions, corn in Indiana would produce about 6 bushels a day. Reduce that to dry matter, it comes to about 300 pounds. So if you just start out with the idea that the best producing crop, the highest producing crop under the best conditions will make about 300 pounds a day, that is a good place to start from. Of course, you have to have the temperature right and you have to have the water right and you have to have plenty of sunlight, you have this corn thick enough so that you intercept all the light. And there is nothing can beat corn for the time on that one day.

Now, as you go north, your growing season is shorter so you can't produce as much. So no matter how you handle it, as you go north your corn has got to be less. Of course, the corn growers accommodate you by getting corn that has a shorter growing season, but you cut your biomass yield.

Now, come back to Indiana, I don't know of any way you could increase the yield except maybe by using this giant cane. I don't know a thing about it, but since it's perennial and you have got the ground covered, the only advantage the giant cane could have over corn is the fact that it covers the ground a little bit quicker so you could get a little bit more growth out of it.

As you go south, you get the corn that has a little longer growing season and you can grow a little bit more because you have more time, more warm weather.

Now eventually you get down to a place where your corn does not occupy the whole growing season and this is where kenaf comes in. I think that Dale pointed out that a C3 plant produced about two-thirds of what a C4 plant would in rough figures, so you think in terms of 200 pounds per acre per day for a C3 plant. Well, if you have got a season that is too long for your corn to use you can put a little kenaf in and kenaf will grow less per day, but a few more days, so you have got to go fairly far south to get enough time so that the kenaf will give you more dry matter. But again, of course, your giant cane will grow just as fast as corn and will start quite a bit earlier. So you don't gain anything by changing from corn to some of these other things, to kenaf and to the giant cane, until you reach a point where your corn doesn't grow long enough to occupy the whole season.

Now, we come to the question of water. Up close to the cornbelt you hear all these Nebraska people brag about their corn and Iowa people brag about their corn. I don't think many of them know really why they grow it in the cornbelt. You are not in the cornbelt because you have got a more favorable growing season, because it's even better in Kentucky and Alabama and even Florida as far as the growing season is concerned. You grow corn in the cornbelt because you have got a lot of water stored in the ground. You can store about 10 or 11 inches of water. This is just a built-in irrigation system. And where you have got that sort of soil, this is what it takes to get your real production, because in Florida if we don't get rain for a week, why, we have got a pretty serious drouth. Our water storage is less than an inch per foot. Up in Iowa, with 10 inches of water stored in the soil, you can grow corn for a month and a half without rain, without really getting hurt for water. That's the kind of land that you have to put to its most profitable use.

Another point I would like to make is that there is no plant that has a secret way of producing without water. The ratio between water and dry matter is about the same. So there is no magic plant that is going to come on the scene that is going to let you produce more dry matter without water. You can do it with cactus, of course, but your rate of production is pretty low. In general, the C4 plants can produce dry matter with just a little bit less water--that's sort of a new idea, I think--and also less nitrogen. So they have those advantages.

I hope I have given you a picture of how to think about these plants and their ability to produce. Three hundred pounds--6 bushels a day, just remember that figure and then you can start from there and you can figure out how much dry matter you can produce almost anywhere with any kind of plant.

DR. KEIHL: First of all, I want to congratulate those who organized this conference. I think this is a very timely subject, biomass and energy relationships. I have the great addantage over most of you here because I haven't done any actual research in this area. I am in administration and so I observe what is being done.

We do have two pieces of work under way at the University of Missouri. One of our projects involves biomass. We are growing kenaf and some of these crops and looking at anaerobic digestion to produce methane. A second project is using animal wastes in a methane generator. This project is now operational. We have had the usual problems of constructing and this sort of process. In the case of the swine facility, producing methane, it's now operational. We don't have the data of costs and this sort of thing but it's a rather large facility.

The project on using an anaerobic digestion process for field crops will be operational this spring, we hope. We again have had weather problems in construction and this sort of thing.

As laymean viewing this area, I think we have to be concerned because of some of the things I have heard and some that Dr. Duncan just mentioned in the area of crops and utilization of water and nitrogen loss. I was greatly interested in the comments made on soil erosion and I think we have to face up to that problem.

Another problem, as I view it, is the cost of handling bulky materials. And I don't think that farm machinery companies are currently producing equipment for harvesting biomass. We still have the problem of coming out on a net basis and producing energy. We have to take into account the cost of gathering, hauling, storing, and this sort of thing. I think all of us must be concerned about this area and certainly look at this with great seriousness and dedication. Certainly, we here are doing our small part to help produce some answers in this area, particularly from the standpoint of agricultural bulk materials.

MR. MCPHEE: I will be glad to make a few comments about the utility point of view of using straw and cornstalks and other forms of fuel. I also think it might be very helpful to try to answer any questions that anybody has in that regard.

Let me say, first of all, that in the utility business, our job is to provide as low a cost of reliable energy as we can and we are increasingly concerned about not affecting the environment while doing this. Those concerns are considered pretty important by the ratepayers. They want their energy reliable, they want it at as low a cost as possible and they have an increasing concern with the environment.

The utility business is like everything else. It's a new ball game. There are constantly new challenges, new concerns, new things to look at and consider. The possibilities of other fuels is a very attractive idea. However, all attractive ideas have to stand the test of economics, and if it can't stand the test of economics, well, it simply won't be used.

From what I have heard on the talks this afternoon, it doesn't sound as if the farmers particularly want to part with their straw and their cornstalks without proper consideration. This is understandable. On the other hand, it has to be factored in the cost of this product and the cost of using it. And I heard quite a little bit about the preparation of it and how it can be handled and this was all interesting and very informative and sounded like it's realistic, but I didn't hear much about the cost of modifying your boilers and your equipment to handle straw and cornstalks and things like that. I don't know how much per million Btu investment it costs in order to handle biomass.

Certainly there is nothing wrong or there is no lack of attraction in burning any fuel that makes economic sense. Straw with 7,000 Btu per pound, no ash, no sulfur, is very attractive. That would be great if it makes economic sense. We burn coal that's like real estate. It's, oh, slightly better than straw in Btu, 8,000 Btu, 30 percent moisture, 25 to 30 percent ash. Got all kind of problems with it. But we burn it at a fairly respectable rate.

In Kansas City Power and Light our whole system fuel costs last year was 60 cents a million Btu. That is less than the national average. We are in a rather low cost fuel area because we can use local coal. However, our fuel costs are increasingly going up. We are now bringing coal in from Wyoming and that coal is running 70 and 80 and 90 cents a million

Btu. So our fuel costs have gone up. Our cost was 30 cents a million Btu in 1970, 60 cents a million Btu in 1976, and in another few years we will be to a dollar and above as they are in many parts of the country today.

But the figures that I heard on straw and cornstalks sounds like $2 and $3 per million Btu delivered to the plant and then I really think that you have to look awfully hard at the handling at the plant.

But certainly we are looking under every rock that there is for new ideas, new ways of improving costs, reliability and the whole bit. I think it is very interesting the work that is going on in that direction. Hopefully, the work will continue and maybe we can get something out of it.

MR. MILLER: I would like to pursue that very slightly. From my experience in a large research center, I am thoroughly convinced, one, we should be thinking big and, secondly, we must never say it cannot be done. For example, we heard a great deal about erosion and yet we have a development at our research center, something that we have dubbed super slurper. This super slurper, a type of gel, is really a starch bath polymer in which some treatment of ground stabilizes it. There is a great deal of work going on in double cropping in which you can coat with this gel and it will hold the moisture and let the plant get a jump, maybe as much as two or three weeks. There is one company in Illinois who will very soon be coating a great deal of their corn with this gel for their planting and thereby hoping to hold the moisture conditions because the gel is not toxic to crops. Then the crops will pull the water out of this gel and when you get a light rain or irrigate the crops it will hold the water there and make use go a lot farther. Dr. Shrader at Iowa State is experimenting with this gel and I believe that he has found excellent results, particularly in the poorer soils. This is where it particularly works well and there is a lot of work going on in desert countries.

And so I guess what I'm saying, I think we should look at all of these various things even if they come up negative, because we need to know that also. But in the long run, I think we are talking not only near term but long term and we must resolve many of these questions and think ahead.

I guess unless some of our particular members have something to say, we certainly welcome any questions that any of the conference attendees have.

QUESTION: I haven't heart anything the last 2 days about the loss of any trace elements. I have heard about the replacement of phosphorus and nitrogen, but what about the removal of trace elements from the soil? Are there those present or has that not been any problem?

DR. DUNCAN: This is sort of a hard question to answer. One would think it most unlikely that there would be serious depletion of these trace elements for a long time, depending on soils. There are soils that are definitely deficient and in most cases this deficiency is more a solubility problem than it is an actual total amount problem, at least that has been our experience in Kentucky. Some soils lack everything, you have got to supply everything anyway. That is true of some of our Florida soils, I'm sorry to say. But I don't think that's a major problem.

QUESTION: I would just like to expand a little bit on what Mr. Miller said about the cost of bagasse. I have a hard time accepting the $1 per million Btu figure for bagasse because it has just been a generally accepted principle and it has been handled under contract ever since the 1920's that a ton of dry bagasse is worth two barrels of fuel oil. So I think bagasse would be worth $2.50 to $3.00 per million Btu's. Now, this figure is calculated on the basis of getting 80% efficiency with the fuel oil fired boiler. Two barrels of fuel oil have 12 million Btu and 80% of that is 9,600,000 Btu. If you use bagasse at 50% moisture content you get a 60% overall efficiency in the boiler, so it gives you the same 9,600,000 effective Btu. So I think that this figure of $1 per million Btu just has to be changed. It's absolutely wrong and will never be accepted by the sugar industry. They will say, "Well, we can burn the bagasse ourselves and generate steam and power and why should we sell it for a third of what we can get for it."

DR. BUCHELE: When I surveyed the sugar factories they were burning bagasse instead of natural gas in Louisiana at $2.40 per million Btu.

QUESTION: I think you have to put it on the basis of fuel oil because gas is not going to be available for utility use eventually. You have to put it on a realistic value. The price of natural gas in many places in Louisiana in some places is still 30 cents a thousand, which is in long-term contracts, but when those run out they will be paying the intrastate price.

MR. McPHEE: I might comment that our fuel oil is $2.50 a million Btu and you are completely right, the little lead that you can get for a dollar is gone. It's going to go up to $2.50 and $3, and certainly you have got to think in those terms.

QUESTION: I would like to have Dr. Duncan address himself to some of the maximum production of biomass. He mentioned the 6 bushels a day in Indiana. As you move on down into Florida and into the year-round growing seasons, what kind of maximum production do you think of?

DR. DUNCAN: You run into light problems in Florida in the wintertime. You don't get as much growth as you would like, but as long as you can keep a green surface intercepting sunlight you can use your sunlight--the more sunlight you have the more growth you will get, of course, but in maximum figures I don't know that I could give it to you.

QUESTION: You take your 300 pounds a day times 360 days, you have somewhere around 50 ton per acre. Is that ever obtained?

DR. DUNCAN: I was talking about the 6-bushel day as being perfect weather. You might do that down in the tropics on top of a mountain somewhere where it never rained and you supplied the water by irrigation, but that's an absolute top figure.

Could I amend an answer that was given a moment ago? The problem of sugarcane in Hawaii would be the best example of a maximum yield crop and it would be on the leaves that are lost. They are going to plant every 2 years this C4 crop and under ideal conditions or very nearly so the yeild of sugarcane is 40 or 50 tons per acre per year.

QUESTION: Mr. Miller, your figure of 34 cents credit of the distillers' grain to the alcohol is a significant portion of the economics of producing alcohol. What happens when you start producing a lot of alcohol and, therefore, start producing a lot of distillers' grain. How big of a factor of that price of distillers' grain are you going to have? Just knowing the market a little bit myself, I expected the amount you could credit to that distillers' grain is really going to drop when you flood the market with a lot of distillers' grain. Do you have any comment on that?

MR. MILLER: I really can't answer your question. I'm sure that if we got into tremendous volume there would be an effect in here. However, as I say, I only priced the byproduct credit at 34 cents per gallon of alcohol produced and it probably should be priced higher.

Also we must recognize that even the quantity we are talking about is a rather insignificant part of the total protein concentrate market in the United States. I believe this market is something like 30 million tons a year. Maybe even a little bit more. So even if we were producing tremendous quantities of distillers grain it would be a small part of the total protein concentrate market.

QUESTION: Corn is $80 a ton. What I'm asking is can you substitute the stillage directly for corn?

MR. MILLER: The distillers' grains have inherently carried a price higher than you would calculate corn because of their protein content and also because it has gone through a fermentation process and has growth factors which are extremely valuable.

I was interested in the chart that was shown earlier about the relation of corn and distillers' grain. They really aren't competitive with each other because corn has a lot of energy from the starch and distillers grain has essentially no energy. Of course, one thing that is happening right now is that there is a real shortage of distillers' grains and so the price has tended to go up a great deal. This is primarily because everybody is drinking vodka and Scotch and the bourbon distilleries are practically all shut down. Therefore, there is very little distillery grain being produced.

I'm sorry, that's all I can answer. I don't know what effect it would have, but again I point out even with the quantities we are talking about, this protein concentrate would still be a small part of the total protein concentrate consumed in the United States and the world.

QUESTION: I guess one of the kind of side questions I was asking, what kind of terms of production might we be talking about? Would we flood the market by 10 times the amount of distillers' grain we have now or--I guess I'm looking for ideas of the size of plants, and so forth.

MR. LIPINSKY: When you make about 70 million gallons of ethanol per year, then you will get about 3-1/2 million tons of distillers grain. Now, that's a very significant amount and we talked this over with some of the people who sell this material. They have a series of markets that they go into and there is a poultry market that is very large that they could exploit. Right now the grain sells for $120 to $140 per ton, but you are sure to knock the price down 20 or 30% when dealing in large quantities. So this is one of the reasons why we are using about $105 per ton and Mr. Miller uses $100.

QUESTION: There has been some discussion on the use of biomass as a topic fuel for a fossil fire electric generating plant. I wonder if this is economically feasible as well as technologically feasible for generating plants that range in size from 400 to 800 megawatts.

MR. McPHEE: I doubt that this is economically feasible because it will cost $2 to $3 per million But to get the materials there and you would probably need a separate system to burn the material. You can't very well burn it with your coal, you have got to do something else. So having to use a separate system would probably increase the cost another dollar or possibly 2 dollars per million Btu. I think it certainly is a worthy concept if you can bring the economics in line. But from what I have heard, it doesn't sound to me like the economics are very attractive.

Bear in mind also that reliability and continuous availability of your fuel is important. Suppose we are talking about substituting 20% of the fuel with biomass. But will you have the biomass fuel when the snow is 2 feet on the ground? You have to have fuel all of the days of the year to run boilers of that size. Biomass could still have some value on intermittent use, but if it is only there during the fair weather that also is a detraction.

So I would like to see it competitive. It doesn't sound to me like it is, certainly at this point.

QUESTION: Wouldn't it be true, that since fuel from biomass is a very high quality premium fuel, that to not use this topic cycle of a fuse with peaking equipment, much of which is gas fired today, would not give it a price much higher than the coal price. It is nor fair, it seems to me, to compare with the dollar a million Btu fuel from coal when we have such a high quality fuel in biomass.

MR. McPHEE: Well, you have a point, in that if you are going to use the biomass for flame stability or ignition, it has a greater value. Natural gas is what we currently use for flame stability. But coal is the base fuel. And for biomass to be used as a base fuel, it has to be available all the time. I think you have got a problem of availability with it.

So I think you would still be faced with using something else part of the time. It would have, I think, a higher value than coal. I think you are right on that. Instead of comparing the cost with coal, you could probably consider the biomass a having a value of $2 or $3 which is what we pay for oil, for the occasional use for flame stability. But it doesn't sound like you can get biomass for that price.

QUESTION: Well, with today's environmental dictates on burning coal, would not a fuel like this even substantially reduce the capital investment in an Ames boiler?

MR. McPHEE: If you had a reliable supply of this fuel and you could build a unit that would only burn this fuel you could save a substantial amount of capital expenditure. You wouldn't have to put in a lot of coal mills for grinding coal and you wouldn't have to put in $30 million electrostatic precipitators. You would have to put something in but not of near the magnitude. But there would have to be a continuous reliable supply of this fuel. I think under those conditions then you could bring your capital costs down and I think possibly that might be interesting. But I think you have got a real problem on continuous availability. You are going to have to have the straw all the days of the year.

MR. McPHEE: The point I'm making is that if you have it continuously available then you can realize a lower capital investment. If it is going to be intermittently available, then you have to be able to burn coal or biomass either one. Then you are faced with the coal investment plus whatever you have to have for the biomass investment.

QUESTION: In your utility system, do you have peaking plants and if you do what is their size?

MR. McPHEE: Yes, we do have. We are definitely a peaking utility. We have an annual load factor of 48 to 49 percent and this is very low. The average utility will run maybe 55 percent or some of them maybe up to 60. So we use combustion turbines for peaking. We also use old equipment, equipment that is kind of on its last legs and we limit it to the say, 400, 500, 600 or 1,000 hours a year, and combustion turbines are the equipment we are putting in now. They do burn oil.

QUESTION: And they are sized at--

MR. McPHEE: Fifty megawatts each. We have about 10--all the way from 10 to 20% of our capacity in peaking capacity.

QUESTION: I would like to make a couple comments from the farm standpoint. I do have some farm interests. If the price is this $2 which I can convert back to $32 a ton, is that fair? Half or two-thirds of that is not the farm end of it, delivered prices. The farmer reaches a continuous supply, I think year around. I haven't seen a farmer yet that couldn't beat these figures that I have seen here.

The other observation I had was that if you really want to conserve fuel, I mean fossil fuels, we will have to get the price of them up and all these other fuels will be practical again. I think we know this already. I think as prices go up then these fuels will be feasible and will take care of themselves, they will be used then.

MR. MILLER: The comment I have just heard and several things over today and yesterday bothers me a little bit. We get to talking about supply or alcohol production and it appears that all too often it keeps being brought up that we will do this when conditions are such and such and we will do it when we have to have a surplus. Rest assured, I spend many a year in the chemical industry and that is not the way it runs. If you are producing--if you have an alcohol plant, I don't care what size it is, first of all you have to develop the customers for the output of that plant, and so they look to you for supply. So after you have supplied them 1 year the next year you say, "Well, I don't think we will produce alcohol again this year, it is a little better to sell the grain or ship the grain to Russia or something like that." Rest assured, you come back to start that plant again you don't have customers any more and you are not going to get customers. So if you are going to put in a plant, you have to certainly set a base production, at least, for your fixed customers on contract and supply that year after year on a regular basis. Otherwise, you just might as well forget that plant. And that's the way that I have seen industry work. Except in times of real shortages, you can't sell that material and the probability is that when you get ready to start that plant up again you don't have shortages then.

MR. LIPINSKY: May I just say one thing about bagasse. The sales value of bagasse is likely to be well above $1 per million Btu, it might be $2 or more. The $1 that we have been using is the costs that are attributable to getting it there, getting it separated, storing it, and so forth. In other words, it's about a dollar per million Btu cost. Now, once you have got the bagasse or other residue it is a question of how much you can sell it for. If you have it right here at this particular facility and it's your own ammonia plant it may be that you are buying it from yourself at a transfer price. But it certainly is true that if the price of electric power or something else went up enough, then that man has got the classic problem that everybody who processes corn or anything else may prefer to do something else with their residues. So we have to keep our costs attributable to getting something there versus what we can sell it for.

PARTICIPANTS

Mohammed Hamid Abdallah
Graduate Student (PH.D)
Ohio State University
2120 Fyffe Road
Columbus, OH 43210

Y.K. Ahn
Supervisor
Gilbert Associates, Inc.
PO Box 1498
Reading, PA 19603

Seward E. Allen
Agronomist
TVA - National Fertilizer Center
Muscle Shoals, AL 35660

Everett Anderson
President
Lakeside, Inc.
PO Box 812
Eagle Lake, TX 77434

Dr. Joseph E. Atchison
President
Joseph E. Atchison Consultants
30 East 42nd Street
New York, NY 10017

Dr. R.C. Bailie
Professor
Chemical Engineering
West Virginia University

Robert Bash
Director, Local Activities
Ohio Farm Bureau
245 N. High Street
Columbus, OH 43216

Edward J. Bishop
Manager - Agric. Materials
Chemicals Division
Quaker Oats Company
Merchandise Mart Station
PO Box 3514
Chicago, IL 60654

Robert H. Boecking
Resource Conservationist
USDA-Soil Conservation Service
Federal Building-U.S. Court House
Lincoln, NE 68508

R.H. Bogan
Professor
University of Washington
303 More Hall
Seattle, WA 98112

L.L. Boyd
Assistant Director
Agricultural Exp. Station
University of Minnesota

P. Broekhof
Staff Specialist
A.G. McKee
10 S. Riverside
Chicago, IL 60606

Dr. Robert M. Busche
Central R & D Department
duPont Company
6003 duPont Building
Wilmington, DE 19898

Robert J. Calcaterra
Technological Forecaster
Standard Oil Company (Indiana)
Amoco Research Center
PO Box 400
Naperville, IL 60540

Diane Calden
Resource Engineer
Pacific Gas & Electric
245 Market Street
San Francisco, CA 94106

Raul R. Cardenas, Jr.
Professor of Civil Engineering
Polytechnical Institute of NY
333 Jay Street
Brooklyn, NY 11201

Jim Cochran
Terra Chemicals
Sioux City, IA

Dr. Brian L. Crissey
National Academy of Science

Shirley Dimmitt
Environmental Scientist
Black & Veatch Consulting Engineers
1500 Meadowlake Parkway
Kansas City, MO 64114

Giles Dixon
Research Director
American Plant Breeders
5201 Johnson Drive
Mission, KS

Jerome E. Dobson
Research Associate
Oak Ridge National Lab
Oak Ridge, TN 37830

William Eaton
Valley Mont
Nebraska

Kent Ernest
Stanford Research Institute
333 Ravenswood Ave.
Menlo Park, CA 94025

Gary Foutch
Graduate Associate
University of Missouri - Rolla
Chemical Engineering Department
Rolla, MO 65401

Lloyd R. Frederick
Professor - Soil Microbiology

Wallace A. Gieringer
President
Jefferson County Industrial Foundation
Box 6866
Pine Bluff, AR

Charles Gonnerman
Mueller Associates
1900 Sulphur Spring Road
Baltimore, MD 21127

John L. Hickson
Hickson Consulting Services
5915 Bradley Blvd.
Bethesda, MD 20014

Stuart H. Hoffer
Marketing Manager
Hamilton Standard
Bradley Field Road
Windsor Locks, CT 06096

Dr. Gary Horton
Senior Applications Chemist
Gulf Oil Chemicals Co.
9009 W. 67th Street
Shawnee Mission, KS

J. Larry Inglis
Research Engineer
Farmland Industries
PO Box 7305
Kansas City, MO 64116

Dr. Don L. Isenberg
Senior Scientist
Beckman Instruments, Inc.
6200 El Camino Real
Carlsbad, CA 92008

Dr. Donald L. Johnson
Director Industrial Products R & D
A.E. Staley Manufacturing Company
2200 E. Eldorado
Decatur, IL 62525

Dr. David Junge
Research Associate
Oregon State University
1919 Beca
Corvallis, OR 97330

E.A. Kirchner
Manager
Process Engineering
A.G. McKee
10 S. Riverside Plaza
Chicago, IL 60606

Carl W. Kruse
Mid-America Nazarene College
1210 Willon
Olathe, KS 66061

Dennis K. Kuhlman
Research Assistant
Kansas State University
Dept. of Ag Engineering
Manhattan, KS 66502

Lory Larsen
Research Engineer
Southern California Edison
PO Box 800
Rosemead, CA 91770

Carlos A. Lemme
Senior Economic Evaluation Engineer
U.S. Industrial Chemicals
99 Park Avenue
New York, NY 10028

William P. Martin
Professor & Head
Soil Science
University of Minnesota
St. Paul Campus
St. Paul, MN 55108

Jess Matthews
Rice Farmer - Grain Elevator - Mill etc.
1260 Sheridan Drive
Beaumont, TX 77706

G.W. Meckert, Jr.
Director of Systems Development
Thermonetics, Inc.
Oklahoma City, OK

C.J. Melkovitz
Keo Farms
PO Box 123
Keo, AR 72083

Kathy Miller
Stanford Research Institute
333 Ravenswood
Menlo Park, CA 94025

Paul Mueller
Iowa Development Commission
250 Jewett Building
Des Moines, IA 50315

Don Myhre
Center Director
University of Florida
Belle Glade, FL

Albert S. Nemir
President
A.S. Nemir Associates
Suite 1230 Penn Building
Washington, DC 20004

Dr. E. James Newitt
Specialist
DuPont Company
CR&D Department
Wilmington, DE 19898

Martin Okos
Assistant Professor
Purdue University
W. Lafayette, IN 47907

Dr. Daniel J. O'Neil
Head, Materials & Chemical Technology
Georgia Institute of Technology
Engineering Experiment Station
Atlanta, GA 30332

Robert M. Peart
Professor
Purdue University
Agricultural Engineering
W. Lafayette, IN 47907

Glenn Pirtle
Vice President
Field Services
Ohio Farm Bureau
245 N. High Street
Columbus, OH 43216

David Salo
Mitre Corporation
Westgate Research Park
McLean, VA 22101

Wayne E. Shannon
Manager, Energy Programs
Lockheed
3251 Hanover
Palo Alto, CA 94304

G.K. Scharfenberger
Manager
New Venture Development
Terra Chemicals International
PO Box 1828
Sioux City, IA 51102

Pamela Sheppard
3043 Wold Avenue
Cincinnati, OH 45208

Paul H. Sidles
Associate Physicist
Ames Lab - ERDA
Iowa State University
Ames, IA 50011

Anthony J. Sinskey
Associate Professor Microbiology
MIT
Boston, MA

E.L. Skidmore
Soil Scientist
USDA
Agronomy Department
Kansas State University
Manhattan, KS 66506

Craig W. Smith
Engineer
Burns & McDonnell
PO Box 173
Kansas City, MO 64141

Ron Sorensen
Chief Forester
Minnesota Power & Light
30 W. Superior Street
Duluth, MN 55802

Jeffrey Stallings
Marketing Specialist
Energy Inc.
PO Box 736
Idaho Falls, ID 83401

Frank S. Stanwyck
Union Carbide Corp.
270 Park Avenue
New York, NY 10017

Larry Thompson
Assistant Works Manager
Terra Chemicals
PO Box 100
Seargeant Bluff, IA 51054

Ted Thornton
Agricultural Economist
USDA - ERS
500 12th Street S.W.
Washington, DC 20250

Dr. Cornelius Van Bavel
Department of Soil & Crop Sciences
Texas A & M University
College Station, TX 77801

Walter T Walawender
Associate Professor
Durland Hall
Kansas State University
Manhattan, KS 66506

Ronald Weiss PH.D
Director, Planning
Miles Laboratories Inc.
1127 Myrtle
Elkhart, IN 46514

Mike Witte
Technical Analyst
Division of Energy - State of Illinois
222 South College
Speingfield, IL

☆U.S. GOVERNMENT PRINTING OFFICE: 1978-740-092/212