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CONTINUATION OF SYSTEMS STUDY OF FUELS FROM GRASSES AND
GRAINS: PHASE 2 AND PHASE 3

Final Report

By

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Midwest Research Institute
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PREFACE

This report was prepared for the United States Department of Energy, Fuels from Biomass Program, under DOE Contract No. EG-77-C-01-4042.

Technical monitors for the program were Ms. Anne S. Fege and Dr. Roscoe F. Ward. Special contributions to the program were made by Drs. William D. Shrader and Walter F. Wedin of Iowa State University.

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SUMMARY

This report presents results of an investigation of biomass-derived fuels from grasses and grains. The work is a continuation of a study (Contract No. E(29-2)-3729) which focused on the potential availability of biomass from grasses and grains grown in the continental United States, and on possibilities for enhancing available quantities, primarily through introduction of new crops and by bringing additional acreage into production.

The prior study indicated that if one excludes the current grains on the basis of not being available for alternate use, the principal available resource consists of crop residues and a relatively small fraction of the forage crops, with annual quantities sufficing for delivered-to-conversion plant energy of about 4 quadrillion Btus. By combinations of utilizing marginal land and modifying quantities of grain grown for export and for livestock use, the annual contribution might be approximately doubled. However, the assumptions made with regard to marginal land were arbitrary, and in many instances this may not be compatible with long-term conservation needs.

The earlier study touched only peripherally on costs of biomass, but this factor is addressed in considerable detail in the present study. The present study shifted to a region-by-region analysis of biomass production, with both the present (near-term) and the future (mid-term) being considered. The overall approach for analysis of the near-term involved least cost analysis of production, transportation, and energy conversion. The mid-term analyses were structured around the assumed implementation of modified crop production systems in which land was more extensively used in a given region, improved crop management practices were used, and the crop mixes were significantly altered from the present.

The production systems in the several regions were combined with conversion plants ranging in size from 500 oven-dry (OD) tons/day to 3,000 OD tons/day, or an energy input of 75×10^8 Btus to 45×10^9 Btus using 7,500 Btus/lb. The conversion processes consisted of anaerobic digestion, fermentation, direct combustion, and thermochemical conversion. The latter process was also considered in the context of production of ammonia and methanol. The products thus consisted of ethanol, synthetic natural gas (SNG), intermediate Btu gas (IBG), steam, electricity, ammonia, and methanol.

The at-the-farm production costs of grass and grain increase in the order: crop residues, whole plant biomass, and grains. Crop residues are least costly because a significant fraction of the overall

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cost of producing the crop (grain plus residue) is assigned exclusively to the grain; the preharvest costs and grain harvest costs are thus assigned to the grain and not to residues.

The crop residues have not however, been evaluated as pure wastes, but as commodities which must accept certain costs. One of these is a nutrient replacement/conversion cost which covers the costs of replacing nutrients ordinarily returned to the soil for use by the next crop, of compensating for benefits of organic matter return, and of providing better management to compensate for the values of residues in retaining moisture and preventing erosion. Two other costs have been assessed against crop residues, namely a management charge and a land charge. These factors translate to a field-side cost of crop residues of the order of \$30/ton (air dry). After further allowances for moisture content in the field-dry state and for handling and storage losses, costs on an oven-dry basis are in the \$35 to \$38 range. Transportation costs for delivery to a regionally located conversion plant increase costs to about \$40/oven-dry ton, or of the order of \$2.70/MM Btu.

Whole plant biomass crops, i.e. "grasses" grown solely for biomass, have an approximate at-the-farm cost of \$40/ton; with regional transportation costs added, the delivered, oven-dry costs are about \$50/ton. Grains on a delivered oven-dry basis range from \$75 to \$80/ton for corn and sorghum grain in certain regions to over \$100/ton for some other grains.

For regionally located energy conversion plants, transportation costs for 500 to 3,000 OD ton/day plants are a relatively small part of total costs, or about 7 to 15%. Transportation costs would become a much more significant factor if the biomass were transported to nonregional plants 100 miles or more from the production area, a factor favoring the regional or decentralized energy production system.

The relative contribution of biomass production, storage, and transportation costs to ultimate energy costs (for SNG, methanol, etc.) is usually in the 40 to 60% range. The relative contribution of delivered-to-the-plant costs are, of course, factored upward in inverse proportion to the efficiency of the process for translating delivered energy to product energy, by a factor ranging from nearly 5 (for electricity) to 1.4. The net result is energy costs which compare unfavorably with the present range of costs for energy products, given the facts that the present analysis indicates that the least expensive biomass comes from a unique and limited situation (grass seed hay in Oregon, cost about \$20/OD ton, \$1.35/delivered MM Btu) and that the next least costly biomass-crop residues--is about twice as costly.

The analysis conducted for crop residues can be tempered and made considerably more attractive if the residues are viewed as pure by-products or wastes, and thus are available for little more than harvesting-handling costs plus incentive profit margins. This situation would likely be close to reality in the fledgling, grass-roots early stages of development of residue oriented energy. In other words, the farmer-producer may, at first, be receptive to a moderate return above his obvious costs of harvesting and hauling residues. Serious and substantial development of such an energy industry can be expected, however, to result in involvement and recognition of added costs and penalties associated with residue harvest, and a compensating escalation of costs.

The relatively pessimistic perspective which comes from cost-focused evaluations brightens when regional analyses of mid-term biomass production systems are carried out. The source of the optimism relates principally to quantity rather than cost, however. Production costs are not envisioned to be significantly lessened relative to current costs by improved management practices or with new crops oriented as they should be toward reasonably high yields per acre of biomass. One particularly important factor in this connection is land costs; if this cost could be developed uniquely and independently of costs for land for grain crops, biomass costs could be significantly reduced. A further consideration is the cost effectiveness of improved management practices and fertilizer use, which is a function both of cost per ton or bushel, and of returns for the farm as a whole. Additional fertilization may thus actually increase costs per ton, which up to a certain point are compensated for, in the total farm, by increased yields.

Mid-term analyses of a Nebraska/Iowa multi-county region were conducted within a general framework of improving management practices for the present array of crops, chiefly corn, soybeans, oats, and hay or forage crops; of adhering to conservation, tillage and rotation systems which maintain or enhance productive capabilities; and of bringing marginal land into production. Four modified cropping systems ranged on the one hand from a hay dominated system to a corn-soybeans dominated system at the other extreme in which marginal lands were terraced. The total biomass produced from these modified systems, with improved management, was essentially the same for all four systems, at about 11.5 million tons of grain, available crop residues and hay. The biomass available for energy use was evaluated in terms of maintaining the region's present livestock industry and its contributions to grain markets. The biomass available for energy use under these modified systems is of the order of 17,000 to 18,000 OD delivered tons per day, which is about 40% more than the region could supply presently from crop residues. These quantities (17,000 to 18,000 tons/day) could be produced in an area of about 6,400 square miles, with 3.9 million acres in production.

Mid-term analyses of a south-central Georgia region show that the potential exists in this and similar regions to substantially increase biomass available for energy use. The Georgia region has a considerably higher proportion of "underutilized" land, and currently emphasizes soybeans, peanuts, and corn. The corn crop in Georgia does not yield well, and corn is more costly to produce than in the corn belt. The modified cropping systems entailed marginal land use plus decreasing acreages of corn. The acreage made available was hypothetically placed in Coastal Bermuda grass yielding 6 tons/acre. These modifications resulted in marked increases in available biomass from hay and residues, i.e. from about 2,100 OD tons/day currently, to 14,000 to 17,000 OD tons/day. The Georgia region is in general terms representative of conditions in the Southeastern states, i.e. generally adequate to better than adequate rainfall, fairly large acreages of marginal or out of production land, and the capability to grow on such land perennial grass crops at attractive yields--and thus the potential for significant contributions to grass and grain biomass production.

A region in south central Texas was evaluated with respect to two "new" crops, guayule and giant reed (Arundo donax), the latter under irrigation. One million acres of land was placed in production of these crops. The region was selected because of its suitability for guayule production. The Texas region presently produces available biomass for in the 500 OD tons/day range.

With irrigation provided only during the start-up phase for guayule, and yields of 1.5 field dry (FD) tons/acre, the 1 million acres could supply biomass for a 3,700 OD ton/day plant, with a delivered cost of \$3.00/MM Btu. Using recent information on costs of extracting latex from guayule, the combination of latex and energy production would produce about 170 million lb/yr of latex at competitive costs, and about 3,200 OD tons/day of residues usable for energy. If the latex commands a selling price of \$0.50/lb, the residue for energy will cost about \$1.60/MM Btu.

Production of giant reed under moderate irrigation (24 in.) was assumed to result in yields reported for southern France under similar conditions, i.e. 8 tons/acre. The 4 to 5 yr period required to establish mature stands, plus the irrigation costs, result in overall costs which are of the same order as other perennial grass crops, about \$55/OD delivered ton. The crop is accordingly of interest chiefly for its yield potential. The assumed yield resulted in production of about

Giant reed would appear to have promise in the Texas region, or more generally in moisture-deficient regions, for production under nonirrigated conditions and with only modest fertilizer requirements. Also, it is a candidate for growth in higher rainfall regions of the South and Southeast. In the absence of a significant body of information on this plant in the United States it is premature to attempt evaluations under these conditions.

The evaluations conducted in this program have been based on reasonable extensions and assumptions concerning crop yields under field conditions. This framework provides what is considered to be a good representation of what might be achieved on the large acreages which will be required to provide attractive quantities of biomass in either the regional or national sense. This approach recognizes that field yields tend to be less than research yields, and reflects the somewhat lower level of management and the less ideal conditions which are apt to be encountered in the field.

However, the specific yields used in the study, which range from 1.5 tons for guayule, in Texas, through 2.5 to 4 tons for grass/hay crops in Nebraska to 6 to 8 tons for Coastal Bermuda grass and giant reed, by no means represent ceilings, and other crops may also be superior. Particularly intriguing are yield data such as the 15 to 25 tons/acre reported for napier grass in more tropical climates than are available in the United States. The situations in which it may be valid to propose and evaluate crops yielding 15 tons or more per acre deserve study relative to their significance in terms of energy. Conversely, it is quite obvious that yield increases of even 1/2 ton/acre will substantially increase available biomass if extended over millions of acres.

The results of the study serve to indicate two general conclusions. First, it is apparent that reasonable improvements in management practices together with greater utilization of land can significantly increase the quantities of available biomass. The most dramatic increases would appear to be achievable in regions in which rainfall is not a limiting factor, in which grain crops tend to be marginal, but in which perennial grass crops may yield well and could be produced, if a biomass market were established. Less dramatic but still substantial increases could be achieved in regions in which grain and livestock are produced on a relatively intensive basis without impairing capabilities to support the livestock industry and supply food crops.

Second, the costs of grass and grain biomass produced for energy are not presently competitive with costs of other energy sources. The comparative costs undoubtedly will change in the future as the energy cost picture matures. The crop residues are presently the most attractive on a cost basis, but their potential supply or availability is limited by the demand for grain.

Grass and grain biomass produced for energy, whether as residues, grains, or whole plants, could markedly change the basic economic parameters of agricultural production, by providing increased income to the farmer, and increasing markets for labor equipment, fertilizers, and pesticides.

Evaluations of environmental factors lead to two general conclusions. First, it is apparent that an uncontrolled, spontaneous evolution to expanded use of the land resource and harvest of biomass will both degrade the agriculture production resource and increase adverse environmental impacts exemplified by pollution of surface waters. Second, such impacts can be avoided by the exercise of care in selection of crops and crop management practices, and by similar caution in developing marginal lands.

It is indeed possible to effect an overall improvement with regard to managing the land resource and protecting the environment from the impacts of erosion. However, certain impacts which can be anticipated are not readily evaluated and placed in proper perspective. Thus, the increased use of fertilizer may be accompanied by groundwater contamination; and terrestrial ecological systems will be altered by intensification of land use. Such factors deserve further study.

I. INTRODUCTION

Biomass derived from plant matter has several features which make it an attractive part of an overall system for meeting energy needs. First and perhaps foremost, biomass is derived via solar energy, which signifies an essentially inexhaustible resource over time. Second, biomass growth is considered to be an essential part of a complete energy cycle and maintenance of an ecological balance--the carbon dioxide build-up in the environment is potentially quite important in this connection. Finally, we do not utilize a substantial fraction of our harvested biomass; utilization of wastes in combination with biomass produced deliberately for energy use can, in principle, contribute significantly to overall energy needs.

Terrestrially grown biomass encompasses basically both a forestry resource and an agricultural resource, plus possible contributions from land-based aquaculture. In overall terms, the terrestrial resource consists of about 1.9 billion acres in the continental United States, of which about 1.2 billion acres is basically grass and crop dominated, and is classified as cropland, pasture and range, federal range and idle land. The Phase I study which preceded the current study yielded data approximately as follows:

- *The annual rate of production, in the early 1970's, of grass and grain biomass on the approximately 1 billion acres of cropland, pasture, range, and federal range is about 1.25 billion OD tons, including crop residues.

- *The grain or food crop component of this production, on slightly more than 200 million acres, is about 270 million OD tons. The residue component is about 377 million tons.

- *Forage production, of harvested annual and perennial crops plus cultivated crops harvested by grazing, is 105 to 110 million tons.

- *Unharvested grasses on pasture and range produce the remaining biomass, of the order of 500 million tons.

Considered in terms of potential availability for energy use, the following conclusions were reached:

*The grain crop is presently dedicated to established markets for livestock feed, human consumption and miscellaneous uses. Excess production, e.g., in good crop years, could be made available, but is not an assured supply. A steady supply could be provided in limited regions, but creation of a substantial nationwide reserve for biomass would require bringing additional acres into production.

*The forages are committed to livestock. However, a fraction is not consumed by livestock, and perhaps 10% is available for energy use.

*The grass growing on pasture and range is in part dedicated to livestock, to the extent of about 200 million tons annually (equivalent corn basis). The remainder, 250 to 300 million tons, is accordingly not harvested by grazing animals and might be viewed as available for energy use. However, the average "available" yield (that left after grazing) over the entire country is only about 0.4 tons/acre. This factor precludes economy of harvest and transportation. Further, good management of the pasture and range resource actually grazed by livestock requires retention of a significant fraction of the above ground biomass to prevent erosion, retain moisture, and insure continuing productivity. The pasture and range resource is accordingly not considered as a source of available, reasonable-cost biomass.

Crop residues thus constitute the major source of grass and grain biomass potentially available for energy use at present. However, the total quantity of above ground residue biomass is not available. Some must be left behind because 100% harvesting is not possible, and some must be returned to the soil to minimize erosion and maintain soil properties. The quantities which should be left on the land vary with the crop, the cultural system, soil types, climate, and disease problems. In the grass seed industry in Oregon, at one extreme, essentially complete annual removal of straw is necessary to maintain high levels of productivity; burning formerly was standard practice. With soybeans, the residues are relatively small in quantity, and complete retention on the land is preferred. Somewhat arbitrary assumptions about residue quantities which could be harvested for biomass yielded the result that 277 million tons, out of 377 million tons, might be harvested for energy use. This quantity combined with 10% of the forage crops sums to a total 289 million OD tons annually, or about 4.3 quads of delivered-to-the-plant energy.

Assuming that 73 million acres of marginal or underutilized land could be brought into production using selected high yielding crops dedicated to energy use resulted in an estimated increase of 168 million OD tons. When combined with 289 million tons of residues and forages, the yield of available biomass became 457 million tons, or about 6.9 quads. Arbitrary exercises in which reduction of grain fed to cattle and reduction of grain exports were assumed, with vacated land diverted to biomass production, added modest amounts to the available quantity: 95 million additional tons (total of 552 million tons), to increase the available quantity to 8.3 quads.

Some perspective on the potential to increase the quantity of available biomass is provided by examining an assumption of an across-the-board increase in yield per acre. An increase in yield of 0.5 OD tons/ acre on 1 billion acres would result in 500 million annual tons of grass and grain biomass, above current production. Such an increment would add 7.5 quads of biomass derived energy, and result in an overall possible contribution from grasses and grains of 11 to 13 quads. A 1/2 ton/acre increase in yield seems at first glance to be reasonably achievable goal. However, it is a 40% increase on a nationwide basis, and in this light, will not be an easily achieved goal. Speculation and supposition such as the above are thus of little real utility, except to help in understanding the problem. The biomass production capabilities of the United States are better viewed in more regional or local terms, with a perspective of matching biomass production capabilities, present and future, with an energy conversion and use system for the region. Further, economic factors are more easily evaluated in local or regional terms than on a national basis. A local production-energy conversion system lends itself fairly easily to an overall economic analysis including production, storage, transportation and conversion. Also, in local terms, one can more readily suggest and evaluate possibilities for enhancing biomass-for-energy production, since crops adapted to the region can be specifically defined, better crop management can be proposed and evaluated, and more extensive utilization of the overall land resource can be assessed on the basis of existing information on the land resource.

The focus of the present study is accordingly on analysis of eight regions in the continental United States. All of these regions have been analyzed for the near-term situation, which basically is current production. Three have been analyzed for mid-term situations, in which combinations of better crop management, modified crop systems, and more extensive land utilization are proposed. The emphasis has been on an integrated production/energy conversion/cost analysis.

The focus on regional or local systems does not signify an endorsement of decentralized energy systems. It will, in fact, be evident later in the report, that some of the regions selected for evaluation can support energy conversion plants processing 15,000 to

20,000 tons/day, with a maximum haul distance of about 70 miles. A single plant of this size is comparable to a fairly large power plant. Alternatively, multiple 500 to 1,000 tons/day could be supported, with maximum haul distances of the order of 10 to 15 miles and a resulting reduction of transportation costs. Since plant biomass has a packaged density of 8 to 15 lb/ft³, transportation costs and handling problems favor biomass conversion close to the production area; for these reasons, the decentralized approach would appear to be favored. However, other considerations, such as capital investment costs of plant construction as well as social and environmental considerations must be evaluated on a site specific basis before final conclusions are reached.

II. OBJECTIVES

The overall objectives of the study are as follows:

A. With selected regions of the country as study vehicles, an integrated analysis of biomass production, storage, transportation and conversion was conducted in order to more clearly establish costs and assess the capabilities of the respective regions to support biomass-energy production. The analyses included both the near-term situation (for eight regions), and mid-term situations (for three regions) in which significantly modified production systems were developed and evaluated.

Near-term denotes essentially the current agricultural system. Mid-term encompasses reasonable extensions of state-of-the-art production, to more extensive land use, improved management practices, and crops. Mid-term does not include the more speculative crops or systems, such as the genetically modified plants which can be expected as a result of agronomic research.

The biomass crops are integrated within each region with conversion facilities sized from 500 OD tons/day to 3,000 OD ton/day, to permit assessments of costs for producing several output energy forms, namely steam, electricity, synthetic natural gas (SNG), intermediate Btu gas (IBG), ethanol, methanol, and ammonia.

B. Environmental factors were evaluated relative to assumed implementation of biomass production and energy conversion.

C. Policy and institutional factors were analyzed with respect to economic impacts on the regions.

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III. EVALUATION OF NEAR-TERM GRASS AND GRAIN BIOMASS PRODUCTION AND CONVERSION

A. Region and Site Selection

Several criteria were used as a basis for selecting regions of the country for analysis. The criteria include the following:

1. Adequate representation of the major agricultural crop producing regions of the country, since these constitute a major part of the biomass producing resource, as well as the crop producing resource.
2. Adequate representation of various types of agricultural production, as determined by climate, soil, topography and rainfall.
3. Opportunities for marginal land use, i.e., the availability of significant acreages which might be designated as underutilized. This criterion has meaning only if reasonable biomass crop opportunities can be defined for the marginal land.
4. Suitability for assessment of special or unique biomass production possibilities. An example is the use of semi-arid land for growing drought resistant plants.
5. Adequate representation of various kinds of crops.

The above criteria have served as the basis for selecting the regions being studied in the program. Other criteria which pertain to the energy market (i.e., present needs in a region for methane or increased electric power); to the energy distribution system; and to energy plant siting (water supply, utilities, labor, etc.) have not been considered. In other words, it has been assumed that an energy conversion plant might reasonably be located within the biomass production area, and that the output of the energy conversion plant will find a ready market. The above criteria would undoubtedly be considered in siting an actual plant, together with other factors such as the availability of other sources of biomass (silvicultural biomass, industrial and municipal wastes, feedlot wastes, etc.).

Use of the above criteria resulted in selection of eight regions. One is located in the heart of the cornbelt in Illinois, where corn and soybeans are the prominent crops. Another is located further west in the cornbelt in northeastern Nebraska-West Central Iowa, where corn and soybeans are important but where cropping is more diversified than in Illinois and larger fractions of the area are not in crops. A third is located in south central Kansas where wheat predominates,

sorghum grain is an important crop, and the total crop mix is fairly diverse. A fourth is located in Arkansas where rice and soybeans are the important crops, together with some wheat and sorghum. The Willamette Valley in Oregon is primarily a small grain, grass and hay area, with wheat and grass grown for seed production being dominant. A site in South Central Georgia has been selected as a representative of the sub-humid Southeast; corn, soybeans, and peanuts are the most important crops. A site in southwest Texas has been selected primarily as a region in which semi-arid crops could be evaluated; this region currently has relatively small acreages, spread out over a large area, devoted to food crops. Finally, a region in southern California has been selected; the site currently produces fairly large quantities of food crops under irrigation, in a large area.

The selected sites thus provide representation of major crop types and distributions, of varying climatic and soil resources, and provide the opportunity in varying degree to assess marginal land use and new or modified cropping systems.

The locations of the sites are shown in Figure 1, and the counties in the selected sites are shown in Table 1. A summary of site size, and of acreages in crops is shown in Table 2.

The characteristics of the eight regions with respect to soils, climate, marginal land, water availability and other factors are presented below. For the purpose of this report, marginal land refers to that land which could be cropped if extensive farming practices were implemented to protect the soil. It can also be defined as land in Land Capability Classes II, III, and IV. Occasionally, farming practices required to farm marginal land in the region are mentioned, but any further discussion would be beyond the scope of this report.

Arkansas

The soils of this region are derived from windblown and/or water-deposited sediments. The marginal land consists of soils which are often poorly drained or have slow permeability. The region is relatively flat and erosion is not usually a problem. Much of the marginal land is subject to flooding by the various rivers in the region. However, there is great potential for raising biomass crops which are adapted to these moist conditions. Currently, most of the marginal land not being cropped is improved and unimproved pasture, woodland, or idle cropland. Of the land in Land Classes 1 through 10, approximately 450,000 acres in pasture, conservation reserves, land formerly cropped, etc., is in excess of current cropland (2.86 million acres).

a/ Based on map of Free Enterprise
Data System Production Areas

Figure 1. Crop production areas selected for analysis.^{a/}

TABLE 1

COUNTIES IN SELECTED SITESI. Arkansas

1. Crittenden	6. Poinsett	11. Woodruff
2. Lee	7. Arkansas	
3. Monroe	8. Cross	
4. Phillips	9. Lonoke	
5. St. Francis	10. Prairie	

II. Southern California

1. Montgomery
2. San Louis Obispo
3. Kern
4. Kings
5. Fresno

III. South Central Georgia

1. Calhoun	6. Grady	11. Irwin	16. Wilcox
2. Dougherty	7. Thomas	12. Ben Hill	17. Sumter
3. Baker	8. Colquitt	13. Turner	18. Dooly
4. Mitchell	9. Worth	14. Lee	19. Pulaski
5. Crooks	10. Tift	15. Crisp	

IV. Central Illinois

1. Stark	6. McLean	11. Macon
2. Marshall	7. Mason	
3. Woodford	8. Menard	
4. Peoria	9. Logan	
5. Tazewell	10. DeWitt	

V. South Central Kansas

1. Kingman	6. Reno
2. Butler	7. Harvey
3. Rice	8. Sedgwick
4. McPherson	
5. Marion	

TABLE 1 (Concluded)

VI. Nebraska/Iowa

1. Burt, NB	6. Thurston, NB	11. Woodbury, IA
2. Cedar, NB	7. Wayne, NB	
3. Cuming, NB	8. Plymouth, IA	
4. Dakota, NB	9. Harrison, IA	
5. Dixon, NB	10. Mononia, IA	

VII. Oregon (Willamette Valley)

1. Benton	6. Polk
2. Clackamas	7. Washington
3. Lane	8. Yamhill
4. Linn	
5. Marion	

VIII. Southwest Texas

1. Zavala	6. Live Oak
2. Frio	7. Duval
3. Dimmit	8. Jim Wells
4. LaSalle	
5. McMullen	

TABLE 2

REGION CHARACTERISTICS, CURRENT CROP PRODUCTION

	<u>Total Acres</u> <u>(10³)</u>	<u>Crop Acres</u> <u>(10³)</u>	<u>Grain Crop</u> <u>Acres (10³)</u>	<u>Forage/Hay</u> <u>Acres (10³)</u>
Arkansas	4,859	2,862	2,862	-
California	14,093	1,309	950	359
Georgia	4,966	1,170	1,128	42
Illinois	3,910	3,017	2,931	86
Kansas	4,915	2,613	2,309	304
Nebraska/Iowa	4,151	2,834	2,388	446
Oregon	8,138	698	529	169
Texas	6,479	483	414	69

Large acreages of forestland is cropland quality. Without encroaching on forestland, only about a 10 to 12% increase in cultivated acreage is possible. For this reason, mid-term cropping systems were not developed for this region.

The region is hot and humid during the growing season. The average frost-free period in the northern part of the region is 218 days; in the southern part it is 228 days. The average annual precipitation is approximately 53 in., most of which falls during the growing season.

The soils are primarily silt loams to silty clays and clays. Because of the high average annual temperature, the soil-forming process is continuous and organic matter is broken down quickly. This results in acid soil conditions which cannot be buffered in the soil because carbonates have long been leached from the soil profile.

Low organic matter content also means slower infiltration rates and prolonged wet soil conditions on fine-textured soils. Lack of aeration to the root zone is damaging to most field crops grown under these conditions. The addition of fertilizer (N, P, and K) is important in this region because the high precipitation rate serves to leach out soil nutrients. Overall, this condition results in a fast input-output of both macro and many micro soil nutrients.

Water of good quality is readily available from shallow groundwater aquifers, reservoirs, and natural streams and bayous. Water is currently used for the flooding of rice paddies. Although other regional crops are sometimes irrigated, it is not a general practice in this area of relatively high precipitation.

California

Marginal land in the California region can be put into three general categories: (a) areas dominated by moderately coarse to moderately fine textured saline-alkali soils; (b) areas dominated by coarse to fine textured saline-alkali soils with a high water table; and (c) areas of excessively drained, easily eroded soils. The soils in the first category are droughty, poorly drained, with very low permeability. Soils of the first and second category would require subsurface drainage systems in order to become arable land.

In this region, most of the land available for cropping is in fact being cropped. Of these crops grown in the region, the vast majority are grown in the San Joaquin Valley, which is probably the most productive region in the country.

Rainfall is minimal and annual amounts depend on elevation and location in the valley. On the San Joaquin Valley floor, annual rainfall ranges from 6 to 12 in. There are approximately 200 to 300 frost-free days depending on the location in the valley.

The saline-alkali conditions prohibit use of some of the marginal land, but these soils are often reclaimed because it has become economically feasible to do so. Soils of the more steeply sloped land present erosion hazards. However, vineyards and orchards have been successfully established on these soils.

Mineral deficiencies in crops can occur, but depend on soil type and type of crop grown. Some deficiencies that have been observed on various soils are: iron in corn, sorghum, rice, and other cereal grains; boron in alfalfa; zinc in alfalfa, barley, beans, cotton, sorghum, tomatoes, and other cash crops.

Good quality water is available from deep groundwater aquifers and from surface aqueducts. Water is fairly expensive in this region, and is used primarily for irrigation of crops.

Georgia

The majority of soils in this region are sandy to loamy and well drained. Some are excessively drained and droughty. Lowlands are characterized by fine-textured soils consisting of loamy to clayey surface soils and clayey subsoils. These soils are subject to flooding or excessively wet conditions.

Probably 50% of the tillable land in this region is in crops. Woodland occupies much of the rest of the land in Soil Capability Classes I through IV. Wet conditions in low lying areas restrict their use to crops adapted to wet environs. Crops on marginal land are: peanuts, corn, wheat, soybeans, sorghum, and bermuda grass hay.

Fifty inches of rain is the average annual rainfall for the district with two-thirds falling during the growing season. There are an average of 240 frost-free days in the north, and 260 days in the south.

Due to warm temperatures which oxidize the organic matter quickly, the soils are fairly low in organic matter. The high annual precipitation rate also leaches nutrients from the soil which necessitates heavy application of NPK fertilizers. Soil pH is acidic and frequent liming is necessary to retain productivity. Trace elements such as zinc and calcium are also deficient in many instances.

Because of the coarse textures and low organic matter content, water retention on the sandier soils is low. The lowlands have the opposite problem.

Excellent quality groundwater is readily available from both shallow and deep aquifers. Shallow wells (25 to 200 ft) provide domestic supplies for homes and some irrigation. Deeper wells (200 to 600 ft) also provide excellent irrigation water and wells at 900 ft are being used to meet public supply needs. Surface waters are of good quality and plentiful. Small reservoirs and ponds are often used to store water so it is immediately available for farming needs.

Illinois

Most land in the Illinois region is arable and in production. Farming of marginal land (Classes III and IV) is primarily restricted because of slope characteristics, making erosion a problem. However, on some land, tillage is limited due to the gravelly or cobbly conditions of the soil which has derived on glacial till. These particular soils are excessively drained and low in moisture content and nutrient-holding capabilities. Since the region presently is very intensively cultivated, with high biomass quantities derivable from crop residues, marginal land area and productivity is not essential to biomass production considerations.

Most of the soils in the Illinois region are derived on loess and/or alluvium, are well-drained, and are high in fertility. Their primary use is the raising of corn, oats, wheat, and soybeans.

The average annual precipitation for the region is 39.5 in., most of which falls during the growing season. There are between 170 and 180 frost-free days in the region.

The arable soils of the Illinois region are of excellent fertility, have good organic matter content, good infiltration and water retention capabilities, and crops grown on these soils are usually free of any mineral deficiencies. Occasionally, manganese deficiency in wheat, oats, and soybeans occurs on certain soils under specific conditions.

Good quality surface water is available and ponds are common in the region for storing water for farm usage. Irrigation is very limited, and is generally not economically feasible for the crops grown in the region.

Kansas

The soils comprising the marginal land in the Kansas region range from sands to silty clays. The major farming limitation is their erodibility. In Butler and Marion counties, most of the marginal land

is in production--the rest of the land is in range or pasture, due to the shallow A horizon, where bedrock is at or near the surface of the soil. In the rest of the region, the majority of the marginal land is used for crops, the remainder being used for range and pasture. There is some potential to establish a new biomass crop on the range/pasture lands. However, the poorer lands are extensively used for the livestock production. Crops grown in the region are wheat, sorghum, corn, alfalfa, soybeans, and other small grains. About 50% of the counties have increased acreages in cultivated crops since the CNI inventory of the 1960's. As a consequence, less than 1,000,000 marginal acres, exclusive of rangeland, is in principal available for use in support of energy crops.

Average annual precipitation is 29 in. in the west, and 32 in. in the east, of which approximately 70% falls during the growing season. The frost-free period for the region is about 190 days.

The arable soils in the region are of excellent fertility. They are well buffered and usually range in pH from 5.7 to 7.3. Organic matter content is usually good, unless the soils are coarse textured and continuously cropped. Drainage is generally excellent with the only problems being in the finer-textured soils of bottom lands along streams. Water retention and water availability of the soils in the region is very good with the only problems existing on the coarse-textured soils such as fine sandy loam and loamy fine sand, which tend to be droughty. Zinc deficiency in corn is a minor occurrence.

Surface water in this region is of good quality, with some exceptions. The Whitewater River in west Butler and south Marion Counties, Rattlesnake Creek in Rice, Reno, and Barton Counties, and the South Fork Ninnescah River in west Kingman County are saline and precautions must be taken if used for irrigation. There are also some deep groundwater aquifers in the western portion of the region not suitable for irrigation. In the eastern portion of the region (Butler County) groundwater is not plentiful. Irrigation is not extensive in the region, with McPherson County being the most extensively irrigated county with 17,000 acres. The limited use of irrigation is mainly due to economics.

Nebraska-Iowa

The soils of the Nebraska-Iowa region are most commonly silty to silty clays, although sandy soils derived on stratified alluvium are not uncommon. The main restriction for most marginal land is slope, and consequently, erosive potential on this land is high. Terracing is recommended on these lands, although it is not widely practiced. Other areas, such as lowland, have drainage problems and it is not uncommon to find tile and surface drainage systems in these areas.

Crops commonly grown on the marginal land are corn, soybeans, wheat, alfalfa, and some sorghum. Much of the marginal land is pasture. This region is one of the heaviest beef producers in the country. Most potential agricultural land not in crops is grazed and/or harvested for hay.

Average annual precipitation is 26 in. in the north, and 30 in. in the south. About 75% of the precipitation occurs during the growing season which is 150 days in the north and 160 days in the south.

Generally, the marginal land has good water retention and good water availability. There are excessively drained soils good only for grazing and soils of lowlands which may require tile and surface drainage systems.

Minor mineral deficiencies which occur are: iron deficiency in soybeans on bottom lands; zinc deficiency in corn, soybeans, and sorghum where the top soil has been removed (generally by leveling or terracing practices).

Good quality water is available from groundwater sources and from streams. Irrigation is not extensive in the region.

Oregon

Marginal land in the Oregon region comprises a wide assortment of soil and topographic characteristics. The primary agricultural area is the Willamette Valley which runs the length of the region (north to south). Much of the land in the region is unavailable for biomass production because it is federally owned, rocky, and/or has slopes that are too steep for farming. There is marginal land in the foothills of the Coastal Range with slopes of 0 to 20%, which could be farmed with proper farming practices. Areas which are poorly drained and subject to flooding in winter are common in the region. Most are located in bottomlands along streams or on stream terraces. There is also marginal land of good fertility, but which has a shallow A horizon overlying bedrock, limiting its use to specific crops.

The productive land in this region is intensively dedicated to wheat, grass seed, and small grains, and little opportunity exists for bringing marginal agricultural land into production for biomass crops.

Of the land in the region that has impeded drainage, 32% consists of moderately well-drained soils with moderately slow to slow permeability on terraces or lower hillsides. Another 31% of the land has somewhat poorly to moderately well-drained soils with moderately slow to slow permeability on flood plains, fans and terraces. These

soils need drainage for most uses and are fairly easy to drain. The remaining 37% of the land is very poorly drained due to various physical characteristics and is generally difficult or not feasible to subsurface drain.

Average annual rainfall depends on the location in the Willamette Valley and ranges from 40 to 70 in., 70% of which falls during the period November through March. Only 5 to 10% of the rain falls during June through August (0.5 in./month in July and August). Pan evaporation averages 6.5 in. in July and August. There are approximately 210 frost-free days on the valley floor.

Soils in the region are generally high in organic matter content and usually acidic, below pH 6. The soils are not well buffered because carbonates have been leached from the soil profile. Liming is practiced on most cropped land. The soils of the region are of good fertility and any mineral deficiencies in crops will be of a localized nature.

Water retention capabilities of soils in the region depend on their texture. On the well-drained, coarser textured soils, drought is a problem during the summer months. The finer textured soils fare better during the dry period, although supplemental water will probably be necessary in many areas for crops subject to drought stress.

Good quality water is available for irrigation from the many streams in the region. Total area under irrigation is increasing and is especially important for crops subject to drought stress. Heavy dews are very common and provide some moisture during the summer.

Texas

Fifty-nine percent of the land in the region is in Land Capability Classes I through IV. Of this land, 12% is in field crops (corn, sorghum, peanuts, wheat, oats, etc.) and 84% is in range and pasture land (about 3.8 million acres). The topography of the region is level to gently undulating and there is a wide diversity of soils. Clays, clay loams, and silty clays which are poorly drained are often found in lowlands along creeks and streams. These soils are subject to flooding. Most of the soils in the region are calcareous and many of these contain indurated caliche. Many of the soils have a high erosive potential. The amount of marginal land in relation to presently cultivated land is large due to both a low precipitation regime and insufficient water for irrigation.

On the uplands, the soils are most often loamy or sandy, although clayey soils can be found here too. Most of the upland soils

are fairly easily eroded. Except for the clayey soils, the upland soils are usually well-drained with moderate to moderately slow permeability. Thickness of the soil profile varies and often a highly cemented layer of caliche is near the soil surface making it difficult to raise crops. Native vegetation is mesquite, thorny brush, cactus, and short and mid grasses.

Water retention depends on the location and type of soil. Sandy soils do not have good water retention and dry out quickly. The clays have good water retention, but are droughty. Loamy soils are adequate water retainers with good water availability. On calcareous soils, zinc deficiency (or unavailability) sometimes occurs in corn.

Average annual rainfall ranges from 20 in. in the west to 28 in. in the east, and most falls during the spring and early summer. The growing season ranges from 270 days in the north to 310 days in the south.

Good quality surface water is not readily available. Surface supplies are limited and extensive pumping of groundwater for irrigation has caused an appreciable drop in the water table resulting in a cutback in the amount of irrigation in recent years. The available water is of good quality and is used to irrigate peanuts and corn. To consider irrigation for large supplemental agricultural developments is not feasible. Therefore, use of marginal lands for biomass production must consider plants which are able to survive under droughty conditions.

B. Near-Term Crops and Residues: Present Crop Production

The current distribution of crops, and yields of grain, residues, and forages or hay crops in the eight regions is shown in Tables 3 through 10. Brief descriptions of the crops follow.

The Arkansas region (Table 3) is dominated by soybeans, which occupies about 70% of the total acreage (2.86 million acres). Rice is an important crop, being grown on about 500,000 acres. Wheat is the third major crop (167,000 acres), and small acreages are in sorghum grain (30,000 acres). Soybeans produce limited quantities of residues, and it is deemed essential that the residues be returned to the land. The region's potential to supply biomass presently hinges almost exclusively on rice straw plus some wheat straw. The current potential of the counties in this region is about 1.2 million tons/yr.

As mentioned earlier, the Arkansas region has 400 to 500 thousand acres of underutilized or marginal land not in forest and

TABLE 3

CURRENT CROP PRODUCTION ARKANSAS REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>
Soybeans	2,168	1,412	-
Wheat	167	130	184
Sorghum grain	498	993	1,012
Rice	<u>498</u>	<u>993</u>	<u>1,012</u>
Total	2,862	2,572	1,196

potentially available for augmenting production for biomass. The availability, in actual fact, of this land is reduced somewhat by livestock demands so that perhaps a 10% overall increase in cropped acreage might be made available to augment biomass produced for energy. A second option would involve reductions in soybean acreages, a step which could not be lightly implemented. It is evident, however, that the region could markedly increase its potential contributions to a biomass for energy industry by significantly restructuring the crop mix and bringing a relatively small additional marginal acreage into production. The region is also a candidate for double cropping wheat and soybeans, a ploy which could yield 0.7 to 0.8 tons/acre of wheat grain, and a similar quantity of wheat straw. If this practice were applied to 2 million acres of soybeans, available residues would be increased from 1.2 million tons annually to perhaps 2.8 million tons, while maintaining soybeans production at close to present levels.

Alternatively, if 1 million acres of soybeans were diverted to a managed perennial grass crop, or other crops which combined high grain production with high residue factor the biomass output could be increased by 2.5 to 3 million tons annually (with assumed yields comparable to those proposed in mid-term cropping systems for the Nebraska/Iowa region).

The Arkansas region is thus of interest from the point of view of either marketly altering present crop mixes, or of introducing double cropping systems. The latter is suggested as a topic for further study; and the former as a possibility which would be feasible if economic factors were favorable (biomass for energy comparable to soybean production in terms of profitability) and if food crop demands for soybeans could be supplied by other regions.

The California region (Table 4) is dominated by wheat, barley and hay, with wheat and barley being the largest contributors to biomass residues (2,250 tons out of a total of 2,400 available tons). On a per acre basis, alfalfa is the best biomass crop (6 OD tons/acre on 279,000 acres). If all the acreage in production were diverted to alfalfa at this yield, annual production would be 7.8 million OD tons, or 3.25 times the biomass available from crop residues. The productivity of the region relative to biomass is constrained by the availability of irrigation water, alkaline soils, and further by the market demand for various grain crops. For these reasons, mid-term systems were not projected for the region.

The Georgia region (Table 5) emphasizes corn, soybeans and peanuts. Corn yields are low (50 to 60 bushels/acre) and residues from this source are modest in quantity even though acreages are fairly large--576,000 acres. Peanuts is an essential and profitable crop, and contributes reasonably large quantities of relatively inexpensive residues.

TABLE 4

CURRENT CROP PRODUCTION CALIFORNIA REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>Available Residue 10³ OD Tons</u>	<u>Hay 10³ OD Tons</u>
Corn	28	60	47	
Wheat	312	481	813	
Barley	534	676	1,439	
Sorghum grain	44	77	33	
Rice	32	70	73	
Hay	30			141
Alfalfa	<u>279</u>	<u> </u>	<u> </u>	<u>1,699</u>
Total	1,309	1,364	2,405	1,840

TABLE 5

CURRENT CROP PRODUCTION GEORGIA REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay/Forage</u>
Corn	576	764	293	
Soybeans	260	177	-	
Wheat	19	14	19	
Sorghum grain	13	13	-	
Peanuts	260	386	382	
Hay	25			67
Corn silage	<u>17</u>	<u> </u>	<u> </u>	<u>67</u>
Total	1,170	1,354	693	134

The Georgia region is of interest primarily because of the availability of relatively large acreages of useful underutilized land, as well as for the possibility of diverting marginal land plus corn land to coastal bermuda grass which has the demonstrated potential to yield well.

The Illinois region (Table 6) is for all practical purposes wall-to-wall corn and soybeans. The region with its present crop mix can supply about 15,000 OD tons/day of biomass from crop residues. This figure would be increased by 10,000 tons/day if soybeans were replaced by corn, a suggestion that is incompatible with viable crop rotations and with food production priorities. For these reasons we have not elected to modify the cropping system for the region.

The Kansas region (Table 7) is primarily a dryland wheat and sorghum area with a significant livestock industry. If one excludes the rangeland in the region, only very modest acreages (less than 100,000 acres) are available in principal for adding to its potential for producing biomass. It is apparent that the region is managing its resources (rainfall is somewhat of a limiting factor) well with its current mix of crops. Some increase in available biomass would result from diverting sorghum grain to wheat, but such a move would be incompatible with the overall grain-livestock economy of the region.

The Nebraska/Iowa region (Table 8) is quite diversified in crops and is a major livestock producer. Corn, soybeans, oats and hay are the principal harvested crops. The region has about 1 million acres not now in harvested crops which can be viewed as a significant resource in modified cropping systems. Available biomass for the year of record (1974), from crop residues was about 6,300 OD tons/day (1974 was a poor year, and average yields would be higher). The Nebraska/Iowa region has been used, in this study, as an example of mid-term cropping systems which can significantly increase contributions to biomass energy through more extensive land use and improved management, with adherence to adequate soil conservation practice. The evaluations described later in the report have been conducted on the premise that present commitments to food and livestock are maintained.

The Oregon region (Table 9) is a productive area intensively farmed for wheat, small grains, hay and grass seed on arable lands. It is also situated in a region with extensive timber harvest and accompanying timber residues available for energy use. The region is unique in that grass seed residues should be completely removed (burned if permitted) to maintain high productivity. The grass residues accordingly are viewed as pure by-products, without penalties for nutrient replacement and land costs. No alteration of the basic crop patterns has been proposed for the region.

TABLE 6

CURRENT CROP PRODUCTION ILLINOIS REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay</u>
Corn	1,672	5,413	5,014	
Soybeans	1,105	1,157	-	
Wheat	100	111	176	
Oats	47	39	94	
Rye	6	-	-	
Sorghum grain	0.6	-	-	
Hay	<u>86</u>	<u> </u>	<u> </u>	<u>214</u>
Total	3,017	6,720	5,284	214

TABLE 7

CURRENT CROP PRODUCTION KANSAS REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay/Forage</u>
Corn	35	80	63	
Soybeans	33	17		
Wheat	1,702	1,274	1,784	
Oats	12	6	13	
Barley	10	9	17	
Rye	2	-	1	
Sorghum grain	514	519	-	
Hay	79			77
Sorghum silage	45			122
Sorghum hay	16			28
Corn silage	11			39
Alfalfa	<u>153</u>	<u> </u>	<u> </u>	<u>360</u>
Total	2,613	1,905	1,878	626

TABLE 8

CURRENT CROP PRODUCTION NEBRASKA/IOWA REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay/Forage</u>
Corn	1,445	2,432	1,621	
Soybeans	614	518	-	
Wheat	24	20	28	
Oats	277	223	536	
Barley	5	5	9	
Rye	1	-	-	
Sorghum grain	21	30	2	
Hay	50			50
Sorghum silage	5			16
Corn silage	157			464
Alfalfa	234			585
Cover	<u>1</u>	<u> </u>	<u> </u>	<u> </u>
Total	2,834	3,228	2,197	1,123

TABLE 9

CURRENT CROP PRODUCTION OREGON REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay</u>
Wheat	224	402	695	
Oats	36	27	64	
Barley	35	39	83	
Perennial seed grass	132	81	221	
Annual seed grass	102	142	171	
Hay	154			292
Clover	<u>15</u>	<u> </u>	<u> </u>	<u> </u>
Total	698	691	1,234	292

The Texas region (Table 10) is range dominated, with only a small percentage of its available land in crop production. Some irrigation is practiced. The region presently has little available biomass, and is of interest principally for potential growth of a dry-land adapted crop (guayule), and given irrigation, giant reed (Arundo donax).

The production capabilities of the eight regions are compared in Tables 11 and 12. In Table 11, available residues are compared on the basis of delivered oven dry (OD) tons per day, 330 days/yr. A 5% loss of biomass between harvest and consumption by conversion plant is assumed. Also compared on the same basis are per acre yields of grains, forages, and all biomass (Table 12). Numbers for these three categories--grain, forage, all biomass--are of little significance with respect to an energy plant, and are presented only to indicate general levels of production in the region.

The data in Table 11 single out Illinois, the smallest region, as the largest producer, for three reasons: (1) nearly 80% of the land is in production; (2) corn, a high biomass producer, is the dominant crop; and (3) the region is one of the more productive regions of the U.S. The Illinois region could supply 15,200 OD tons/day of crop residue; if all biomass were used, the energy feedstock would be about 35,000 tons/day.

Five regions (Arkansas, California, Kansas, Nebraska/Iowa, and Oregon) are capable of supplying crop residues in the 3,500 to 7,000 ton/day range; Georgia about 2,000 tons/day; and Texas about 300 tons/day.

Table 12 represents the regions in terms of yields per acre. The per acre yields are in part a reflection of basic productivity from region to region (including provision of irrigation) and in part a reflection of crop mixes. Soybeans represents about 70% of all crops in Arkansas, for example; 0.9 OD ton of soybeans is a respectable yield (34 bushel/acre), and soybean residues do not count toward residue supplied or the aggregate yield per acre even though soybean acres are counted in calculating the "all" yield. Comparisons among regions are not rigorously significant, in other words. The data do show, nevertheless, that Illinois and California (with irrigation) produce well, as does Oregon.

The data for Nebraska/Iowa represent a poor corn year due to lack of rainfall, so both yields per acre and overall production are lower than average for the region. Nebraska/Iowa is a good corn-soybeans-oats-hay region, with yields generally somewhat lower than in the Illinois region.

TABLE 10

CURRENT CROP PRODUCTION TEXAS REGION

	<u>10³ Acres</u>	<u>10³ OD Tons Grain</u>	<u>10³ OD Tons Available Residue</u>	<u>10³ OD Tons Hay/Forage</u>
Corn	32	59	37	
Wheat	26	16	15	
Oats	8	3	7	
Sorghum grain	326	351	20	
Peanuts	22	25	22	
Hay	54			52
Sorghum silage	1.3			6.6
Sorghum hay	12			18
Alfalfa	<u>1</u>	<u>—</u>	<u>—</u>	<u>—</u>
Total	482	454	101	77

TABLE 11

BIOMASS FEEDSTOCK SUPPLY CAPABILITIES OVEN DRY (OD), DELIVERED
TONS/DAY 330 DAYS/YEAR

	<u>Available Residues^{a/}</u>	<u>Forage/Hay^{b/}</u>	<u>Grain^{b/}</u>	<u>Total^{b/}</u>
Arkansas	3,440	-	7,400	10,850
California	6,920	5,300	3,925	16,150
Georgia	1,990	390	3,900	6,300
Illinois	15,200	615	19,350	35,200
Kansas	5,400	1,800	5,500	12,700
Nebraska/Iowa	6,320	3,200	9,300	18,850
Oregon	3,550	840	1,350 ^{c/}	5,740
Texas	290	220	1,300	1,820

a/ No soybean residues; 1 ton corn residue left on land; other crops 0.5 tons; net residue yields less than 0.8 ton/acre rejected.

b/ All forage and grain included.

c/ Food grains only.

TABLE 12

YIELD COMPARISONS FOR EIGHT REGIONS, OD TONS/ACRE, SHRINKAGE INCLUDED

	<u>All Grain^{a/}</u>	<u>Available Residues^{b/}</u>	<u>Forage/Hay</u>	<u>All^{c/}</u>
Arkansas	C.90	1.72		1.32
California	1.44	2.53	5.13	4.28
Georgia	1.20	0.81	3.19	1.86
Illinois	2.29	2.89	2.49	4.05
Kansas	C.83	1.08	2.06	1.69
Nebraska/Iowa	1.35	1.24	2.52	2.31
Oregon	1.59	2.33	1.90	3.25
Texas	1.10	0.24	1.14	1.30

a/ Grain excludes grass seed in Oregon.

b/ No soybean residues included; 1 ton corn residue, 0.5 ton other grain crop residues left on field; net yields less than 0.8 ton/acre rejected.

c/ Sum of yields of grain, residue and forage, divided by total acreage in production.

Oregon is limited in total quantity of biomass chiefly due to the relatively small acreage in production. Yields of wheat are quite good in this region, and the seed grass industry is important and productive.

Kansas statistics reflect the dominance of wheat and sorghum grain. Sorghum grain does not yield sufficient residue to meet criteria for biomass harvest (0.5 ton left on field; net yield of less than 0.8 ton rejected), and wheat at good yields (35 to 40 bushels/acre) is a producer of modest tonnages of grain and available residues.

The Georgia region emphasizes corn, soybeans and peanuts. Corn yields in Georgia (50 to 60 bushels/acre average) are substantially less than in the corn belt; soybeans produce reasonably well; and peanuts is a good crop. Noteworthy are current hay yields (3.2 OD tons), which are higher than averages in all other regions except California under irrigation. However, current acreages of hay in Georgia are low, which is probably due to low demands in that climatic region.

The Texas region, with only 482,000 acres in crops, and about 70% of its crops in sorghum grain, is not a significant current source of grass and grain biomass, except possibly in very local situations. The Texas region is of interest chiefly as a site for new crops.

C. Costs of Producing and Transporting Grass and Grain Biomass

1. Cost Analysis Procedure for Production:

The agricultural production system is composed generally of:

- *A land resource, with its associated costs.

- *A water resource, which is available at no cost from rainfall, and at significant cost if irrigation is employed.

- *An equipment resource.

- *A labor resource--the farmer himself or hired help.

- *Several kinds of resources usually supplied from outside the farm--seed, fertilizers, fuels, and pesticides in particular.

- *A management resource, ordinarily the farmer himself plus possibly services provided by farm consultants, in addition to the resources available through agribusiness firms, publications, universities, extension services, and farm seminars or workshops.

The cost of producing any crop is accordingly the aggregate of those costs associated with owning or leasing land; providing water if needed; buying seed, fertilizers, pesticides, fuels, etc.; owning and operating equipment to prepare the soil, seeding, cultivating, controlling weeds and pests, and irrigate the growing crop and finally to harvest the crops; processing or handling harvested crops as required (e.g., dry grain); storing and transporting to the market; and providing labor and management services. Taxes, insurance, and interest on operating capital are a part of the total cost.

Cost summations for crop production are typically segregated as follows:

- *Preharvest costs, which basically include direct costs for labor, seed, fertilizer, pesticides, fuel, and equipment maintenance.

- *Harvest costs, which are similarly direct costs for harvesting, hauling, drying, etc., the crop.

- *Ownership costs, which include taxes and insurance, but which are chiefly depreciation and interest expenses for equipment.

- *Land costs, or a land charge, which is the cost of owning or leasing the land.

- *Management costs.

It is possible to develop preharvest or harvest costs which include allocated portions of the ownership, management, and land costs to each of the two segments of the farming operation. This exercise would usually have little point or significance, however, since one is usually concerned ultimately with only the total cost of production.

In the event that custom services are contracted for, e.g., custom wheat combining, the same basic cost items apply, except that costs of owning and operating the custom equipment are entered as part of the custom contract expense.

The harvest and preharvest costs are characteristically summed to a total variable cost. The ownership and land costs are termed fixed costs.

The system of cost accounting in general use is based on costs per acre, for the most part. Exceptions are in harvest costs where yield sensitive costs may be computed first for a specific yield and then translated back to a per acre cost. For example, hay baling costs

are more a function of tonnage than of area, and costs per ton are accordingly translated to cost per acre.

Costs for specific elements, and for the entire operation, vary substantially from crop to crop and somewhat less from region to region. The production system is of course geared to costs and profits which are competitive in the market system, and one thus sees a considerable degree of uniformity in production costs per unit of output, given normal yields for the particular region. The variations in specific cost elements and total costs are thus primarily a function of how the farmer--from region to region--can best utilize his overall resources, i.e., will increased use of fertilizer be cost effective, or is land more valuable than land used for the same crop in another region because yields and returns are better.

The land cost item, one of the largest individual cost elements, is sensitive to production and profit potential. That is, land which is capable of yielding 120 to 150 bushels of corn is more valuable than land where yields fall in the 70 to 90 bushel range. The higher land value will be reflected in a higher land charge. Land values accordingly exert a leveling effect on costs from region to region, and within a region as one proceeds from good land to less desirable land. It follows that the land cost item is not easily evaluated and assessed for a particular crop, especially a new one. The remaining cost items are more easily fixed, i.e., seed labor, machinery, fertilizer, and like costs are established by their value in commerce, and there is an excellent base of data on machinery use rates, lifetimes and depreciation rates, repair rates, and fuel use which make it possible to develop costs per acre or per unit of production.

One factor must be particularly kept in mind when evaluating farm production costs, specifically that most farming operations are seasonal rather than year round. In industry, a machine may be used 300 or more days per year, 24 hr/day. In farming, a machine may be limited to use perhaps no more than 20 to 40 days/yr, e.g., by the length of the planting season for a drill or the harvesting season for a combine or baler. This factor impacts machinery lifetime, together with an obsolescence factor, and machinery costs per hour or acre, differently than with an industrial counterpart. In effect, much of the farm machinery is on standby for most of the year; this applies less to tractors and trucks than to drills, harvesters, plows, and like equipment.

The above factor is mentioned to guard against a tendency to expect that machinery costs can be reduced significantly in "mass production" operations. It is indeed true that the costs of a particular machine, per bushel or per acre, are less if more bushels or more acres are processed. But there is an upper limit to the extent that one

machine can be used; above that limit a second machine must be brought into service, or standby machines must be provided to insure that a given crop can be harvested within the available harvest season.

Another factor enters into the costs of machinery use. Specifically, machines whose functions are to work the ground are limited in "capacity" on an area-rate basis, i.e., so many acres per hour. Machines whose function is to process grain or forage are for the most part limited in processing rate to a mass rate--tons per hour or bushels per hour. The latter is particularly significant in connection with biomass harvesting, in that no particular cost advantage incurs for the higher yields per acre. The leveling out point for costs is determined chiefly by tons processed instead of by tons per acre.

With this background, we have employed an existing cost analysis procedure based on the above enumerated general costs items--preharvest, harvest, ownership, land, and management; and on details within each of the general costs items which have been documented for various crops in various regions of the country. These costs include the following:

1. The cost of seed, specific to a crop.
2. The cost of fertilizer and pesticides, specific to usage for the crop and region.
3. The cost of irrigation (if used) specific to the region and crop.
4. Labor costs.
5. Fuel costs.
6. Machinery maintenance.
7. Miscellaneous costs, such as twine, or drying costs.
8. Taxes and insurances
9. Interest on operating capital.
10. Machinery investment costs.
11. Custom costs if applicable.
12. Land ownership costs, which are expressed variously as a percent of land cost (investment basis), share rent, or cash rent.

13. Management costs; in lieu of an item by item accounting, standard practice is to assess this cost at 7% of gross returns.

The above costs do not include a return to overhead and risk. In cost data sheets, this item is simply the difference between costs of production and returns for the crop. For this reason, it varies from a negative to a positive number depending on yield and market value of the crop; if yields are average to good and markets are not depressed, it will be positive; if the opposite is true, it can be negative. It must be recognized, however, that over the long run, a positive profit must be maintained which in effect would slightly increase costs which are presented herein.

The cost data base and economic analysis system used in this program are based principally on the system and data employed in the Firm Enterprise Data System (FEDS), USDA Economic Research Service, Oklahoma State University (Krenz, 1976). The form of the data, and the basic system of accounting and analysis, is indicated in Tables 13 and 14. Table 13 shows the breakdown of costs for a crop in summary fashion. Table 14 presents background information and data which are the basis for development of machinery, labor, fertilizer, fuel, and other costs. Table 14 also contains information on machinery investment costs, operating costs per hour, field rates for tillage and harvesting, times over the field, etc., which permit one to follow through on calculational procedures to arrive at specific costs. Table 14 will also usually contain basic data for arriving at land costs, particularly if a share rent basis is employed.

While the FEDS data and system are the primary sources for cost analyses, cross checks have been made against similar data, less complete, provided by Extension Services. The latter may differ some in detail, but costs are usually consistent with FEDS data.

The FEDS information does not, however, supply all the needed data. In particular, costs for harvesting crop residues cannot be developed directly from FEDS. FEDS does contain data on harvesting hay and forage crops, and such data are points of reference for the harvest of crop residues. However, we have developed a uniform methodology for harvesting residues, based primarily on information developed by Rider (1978). The residue harvesting operation is set up to consist of mowing, raking, baling in large bales, transport to roadside storage, and reloading to a highway-scale truck which transports the biomass to the conversion plant. This sequence of operations permits field drying of residues to an acceptably low moisture content (of the order of 11 to 13% moisture) prior to baling. The residue harvesting costs are all developed for an assumed scale of operation at which machinery and associated costs level

TABLE 13

CROP PRODUCTION COST SUMMARY

PREPARED BY FIRM ENTERPRISE DATA SYSTEM, COMMODITY ECONOMICS DIVISION, ERS IN COOPERATION WITH OKLAHOMA STATE UNIVERSITY, STILLWATER, OKLA. FEEDS BUDGETS ARE PREPARED FOR RESEARCH PURPOSES AND ARE NOT OFFICIAL USDA ESTIMATES OF PRODUCTION COSTS.

TITLE: IRRIGATED CORN FOR SILAGE - NEBRASKA - AREA 400

1975

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST PER ACRE	COST PER UNIT OF PRODUCTION
<hr/>					
1. GROSS RECEIPTS FROM PRODUCTION:					
CORN SILAGE	TN.	14.750	15.270	228.29	
TOTAL RECEIPTS				228.29	
<hr/>					
2. VARIABLE COSTS:					
PREHARVEST:					
SEED	LBS.	0.670	15.900	10.65	0.70
NITROGEN	LBS.	0.192	135.000	25.92	1.70
PHOSPHATE	LBS.	0.250	25.000	6.25	0.41
POTASH	LBS.	0.092	8.000	0.74	0.05
PRE-MERGE HERB	ACRE	5.300	0.970	5.11	0.40
POST EMERG HERB	ACRE	5.900	0.130	0.90	0.06
INSECTICIDE	ACRE	3.800	0.720	2.74	0.18
FERTILIZER APPL.	ACRE	2.500	0.290	0.73	0.05
HERBICIDE APPL.	ACRE	2.000	0.030	0.06	0.00
INSECTICIDE APPL	ACRE	2.500	0.310	0.77	0.05
TRACTOR FUEL & LUBE	ACRE			2.61	0.17
TRACTOR REPAIRS	ACRE			1.63	0.11
EQUIP FUEL & LUBE	ACRE			0.72	0.05
EQUIP REPAIRS	ACRE			1.75	0.11
IRRIG FUEL COST	ACRE			7.44	0.49
IRRIG LUBE COST	ACRE			0.11	0.01
IRRIG REPAIR COST	ACRE			2.68	0.18
MACHINERY LABOR	HRS	2.150	2.912	6.26	0.41
IRRIG LABOR	HRS	2.150	2.700	5.80	0.38
INTEREST ON OP. CAP.	DOLS	0.088	23.343	2.05	0.13
TOTAL PREHARVEST				85.93	5.63
HARVEST:					
TRACTOR FUEL & LUBE	ACRE			3.53	0.24
TRACTOR REPAIRS	ACRE			2.43	0.15
EQUIP FUEL & LUBE	ACRE			0.96	0.06
EQUIP REPAIRS	ACRE			3.52	0.37
MACHINERY LABOR	HRS	2.150	4.658	10.02	0.66
INTEREST ON OP. CAP.	DOLS	0.088	0.0	0.0	0.0
TOTAL HARVEST				23.46	1.44
TOTAL VARIABLE COSTS				108.58	7.11
<hr/>					
3. INCOME ABOVE VARIABLE COSTS				119.70	7.34
<hr/>					
4. OWNERSHIP COSTS (DEPRECIATION, TAXES, INTEREST, INS.)					
TRACTORS				12.41	0.68
MACHINERY & EQUIP				25.51	1.57
IRRIGATION EQUIP				17.58	1.15
TOTAL OWNERSHIP COSTS				55.51	3.50
<hr/>					
5. RETURN TO LAND, OVERHEAD, RISK & MANAGEMENT				56.20	4.34
<hr/>					
6. LAND CHARGE (SHARE RENT)				55.03	3.60
<hr/>					
7. MANAGEMENT CHARGE (7.0% OF GROSS RECEIPTS)				15.98	1.05
<hr/>					
8. TOTAL OF ABOVE COSTS				233.10	15.26
<hr/>					
9. RETURN TO OVERHEAD & RISK				-4.31	-0.31

FOOTNOTES: IRR. ASSUMPT: 100 FT. PUMPING HEAD, 900 GPM, GATED PIPE
AND ELECTRICITY. LEVELING COSTS ARE INCLUDED IN LAND CHARGES.
PRODUCT PRICE USED IS 1/3 PRICE OF ALFALFA HAY.

01/21/77
FEEDS
01/25/77

ENTERPRISE CODE: 884000610
AREA CODE: 25/11/25/12
FILE NO. 475
ACRES REP. BY BUDGET: 77.5 (000) ACRES
ANNUAL CAPITAL MONTH: 9
PERCENT CUSTOM HARVESTED: 0
TECHNOLOGY YEAR 74
DATE PRINTED: 03/01/77

MACHINERY COMPLEMENT NO. 17
NAME SET: 1
PARAMETER SET: 31
HARVESTED ACREAGE AS PERCENT PLANTED: 100.00
EDITION NO. 2

TABLE 14

CROP PRODUCTION COST ELEMENTS

AREA-3/31/37.0 ENTERPRISE-225000000 FILE LOCATION-123 ANNUAL CAPITAL MONTH-2 POSITION-1

IRRIGATED CORN FOR SILAGE - NEBRASKA - AREA 400

1979

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
LINE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	PRICE	SHARE	UNIT	ITEM	TYPE	AMT	
PRODUCTION					NUMBER OF UNITS														
1 CORN SILAGE	3.0	0.0	0.0	0.0	3.0	0.0	0.0	3.0	15.27	0.0	0.0	0.0	14.950	0.400	3.0	161.0	2.0	3.0	
OPERATING INPUTS													PRICE	SHARE	UNIT	ITEM	TYPE	AMT	
														RENT	CODE	CODE			
11 SEED	3.0	3.0	3.0	3.0	15.90	0.0	3.0	3.0	3.0	0.0	0.0	0.0	0.670	0.0	0.0	12.190	3.0	0.0	
12 NITROGEN	3.0	0.0	0.0	0.0	10.00	45.30	0.0	3.0	3.0	3.0	3.0	3.0	0.192	0.000	12.0	211.0	3.0	0.0	
13 PHOSPHATE	3.0	0.0	0.0	0.0	25.30	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.250	0.000	12.0	216.0	3.0	0.0	
14 POTASH	3.0	0.0	0.0	0.0	8.30	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.042	0.000	12.0	216.0	3.0	0.0	
15 PRE-EMERG HERB	3.0	0.0	0.0	0.0	0.17	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.300	0.000	7.0	254.0	3.0	0.0	
17 POST EMERG HERB	3.0	0.0	0.0	0.0	0.13	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.000	0.000	7.0	257.0	3.0	0.0	
18 INSECTICIDE	3.0	0.0	0.0	0.0	3.0	3.72	0.0	3.0	0.0	0.0	0.0	0.0	3.800	0.000	7.0	240.0	3.0	0.0	
19 FERTILIZER APPL.	3.0	0.0	0.0	0.0	0.24	3.05	0.0	3.0	0.0	0.0	0.0	0.0	2.503	0.000	7.0	330.0	3.0	0.0	
20 HERBICIDE APPL.	3.0	0.0	0.0	0.0	3.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0	2.300	0.000	7.0	332.0	3.0	0.0	
21 INSECTICIDE APPL.	3.0	0.0	0.0	0.0	3.0	0.31	0.0	0.0	0.0	0.0	0.0	0.0	2.500	0.000	7.0	333.0	3.0	0.0	
MACHINERY REQUIREMENTS													XXXX	XXXX	POWER	MACH	TYPE	AMT	
															UNIT			CODE	
31 SHREDDER	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.82	0.0	0.0	3.0	99.0	0.0	
32 TANDEN DISA	3.0	0.0	0.0	0.0	1.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	96.0	0.0	
33 CHISEL PLOW	3.0	0.0	0.0	0.0	7.15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	75.0	0.0	
34 SEEDER	3.0	0.0	0.0	0.0	0.22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	65.0	0.0	
35 DRY FERT SPJR	3.0	0.0	0.0	0.0	3.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	77.0	0.0	
36 AMMY APPLIC.	3.0	0.0	0.0	0.0	3.85	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	80.0	0.0	
37 SPRAYER	3.0	0.0	0.0	0.0	0.35	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	84.0	0.0	
38 PLANTER	3.0	0.0	0.0	0.0	1.30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	94.0	0.0	
39 DITCHER	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	94.0	0.0	
40 ROW CULT. M	3.0	0.0	0.0	0.0	3.0	0.0	1.00	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	2.0	92.0	0.0	
41 SPRAYER	3.0	0.0	0.0	0.0	3.0	7.13	0.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	3.0	84.0	0.0	
42 DITCHER	3.0	0.0	0.0	0.0	3.0	0.51	0.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	3.0	84.0	0.0	
43 AMMY APPLIC.	3.0	0.0	0.0	0.0	3.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	80.0	0.0	
44 FORAGE HARVESTER	3.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0	15.27	3.0	3.0	3.0	0.0	0.0	2.300	3.0	92.0	0.0	
45 TRUCK 2 T	3.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	3.0	12.0	0.0	
46 TRACTOR 65-75 HP	3.0	0.0	0.0	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	3.0	12.0	0.0	
47 PICKUP 1/2 T	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	0.0	0.0	0.0	3.0	12.0	0.0	
													SHARE	SHARE	POWER	STYR	LABOR	AMT	
													FIXED	VAR	UNIT	CODE	COEFF	CODE	
49 ACIN IRRIG WATER	3.0	0.0	0.0	0.0	3.0	3.00	3.00	3.00	1.33	3.0	3.0	3.0	1.300	0.100	25.0	95.0	0.180	0.0	

CATEGORY	UNIT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
TOTAL RECEIPTS	DOL.	3.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	228.29	0.0	0.0	228.29
OPERATING INPUT REQUIREMENTS														
SEED	DOL.	3.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.65
NITROGEN	DOL.	0.0	0.0	0.0	0.0	3.0	7.33	16.32	3.0	3.0	3.0	3.0	3.0	25.92
PHOSPHATE	DOL.	0.0	0.0	0.0	0.0	0.0	6.25	3.0	0.0	0.0	0.0	0.0	0.0	6.25
POTASH	DOL.	0.0	0.0	0.0	0.0	0.0	3.74	0.0	0.0	0.0	0.0	0.0	0.0	3.74
PRE-EMERG HERB	DOL.	0.0	0.0	0.0	0.0	0.0	9.11	0.0	0.0	0.0	0.0	0.0	0.0	9.11
POST EMERG HERB	DOL.	0.0	0.0	0.0	0.0	0.0	3.70	0.0	0.0	0.0	0.0	0.0	0.0	3.70
INSECTICIDE	DOL.	0.0	0.0	0.0	0.0	0.0	2.74	0.0	0.0	0.0	0.0	0.0	0.0	2.74
FERTILIZER APPL.	DOL.	0.0	0.0	0.0	0.0	0.0	3.60	0.13	0.0	0.0	0.0	0.0	0.0	3.73
HERBICIDE APPL.	DOL.	0.0	0.0	0.0	0.0	0.0	3.24	0.02	0.0	0.0	0.0	0.0	0.0	3.26
INSECTICIDE APPL.	DOL.	0.0	0.0	0.0	0.0	0.0	0.77	0.0	0.0	0.0	0.0	0.0	0.0	0.77
LABOR COST	DOL.	3.13	3.13	3.13	3.13	3.57	1.93	2.39	2.75	2.45	10.53	0.13	3.13	22.06
INTEREST ON OPER. EXP.	DOL.	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04
TRACT FUEL & OIL COST	DOL.	0.0	0.0	0.0	0.0	0.27	1.31	2.45	0.31	0.0	1.63	0.0	0.0	5.24
TRACTOR REPAIR COST	DOL.	0.0	0.0	0.0	0.0	0.17	0.63	1.28	0.19	0.0	2.43	0.0	0.0	4.05
EQUIP FUEL & OIL COST	DOL.	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
EQUIPMENT REPAIR COST	DOL.	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
IRRIG FUEL & OIL COST	DOL.	0.0	0.0	0.0	0.0	0.0	1.31	2.52	3.32	0.50	0.0	0.0	0.0	7.55
IRRIGATION REPAIR COST	DOL.	0.0	0.0	0.0	0.0	0.0	0.34	0.69	1.07	1.18	0.0	0.0	0.0	2.84
TOTAL VARIABLE COST	DOL.	3.25	3.25	3.25	3.25	19.49	26.34	6.98	6.70	23.96	3.26	3.26	3.26	138.58
ANNUAL LABOR REQUIREMENTS														
MACHINERY LABOR	HR.	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	3.36	7.57
IRRIGATION LABOR	HR.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.70
FUEL REQUIREMENTS														
GASOLINE	GAL.	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.51
DIESEL	GAL.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	15.58
ELECTRICITY	KWH	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	250.29

MACHINERY FIXED AND VARIABLE COSTS PER HOUR														
	HP/	ACRE/	PURCHASE	DEPR./	INTEREST/	INSUR/	TAXES/	OWNER	REPAIR	FUEL	LUBRICANT	OPERATING	TOTAL	
	SIZE	HOUR	PRICE	HOUR	HOUR	HOUR	HOUR	HOUR	COST PER	COST PER	COST PER	COST PER	HOUR	HOUR
MACHINE														
TRACTOR 35-45 HP	45.00	1.300	7350.0	1.040	3.000	0.344	3.122	1.858	2.534	1.292	2.192	2.309		
TRACTOR 50-60 HP	60.00	1.300	9750.0	1.210	3.375	0.340	3.122	2.352	2.665	1.342	2.141	2.744		
TRACTOR 55-75 HP	75.00	1.300	11500.0	1.343	3.720	0.349	3.128	2.820	3.340	1.477	2.177	2.994		
TRACTOR 60-75 HP	75.00	1.300	13100.0	1.423	3.880	0.360	3.154	2.823	3.149	1.413	2.212	2.774		
TRACT 75-100 HP	100.00	1.300	18270.0	1.940	5.143	0.365	3.163	3.120	3.280	1.648	2.247	3.175		
PICKUP 1/2 T	1.50	1.000	4200.0	1.284	1.737	0.337	2.110	1.717	1.307	1.307	1.157	2.211		
TRUCK 2 T	2.00	1.000	11700.0	2.000	2.140	0.163	0.340	5.705	2.940	1.375	3.251	4.247		
1/2 HP TRACT-ELEC.	2.00	1.500	1395.0	1.223	0.223	0.002	0.005	0.058	0.313	0.392	0.315	1.320		
SHREDDER	3.00	0.405	440.0	2.342	0.314	0.035	0.111	1.503	2.158	0.0	0.0	3.158		
TANDEN DISA	16.00	0.133	3740.0	3.353	1.212	0.083	0.233	4.546	3.719	0.0	0.0	3.719		
CHISEL PLOW	14.00	0.164	1945.0	2.813	0.264	0.018	0.344	1.147	1.599	0.0	0.0	2.599		
SEEDER 44	2.00	0.236	1050.0	1.313	0.000	0.001	0.115	2.269	2.437	0.0	0.0	2.437		
DRY FERT SPDR	25.00	0.123	360.0	1.229	0.937	0.0	0.0	1.912	2.508	0.0	0.0	3.508		
AMMY APPLIC.	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
SPRAYER	25.00	0.127	750.0	1.257	0.595	0.001	0.118	2.112	3.409	0.0	0.0	3.409		
PLANTER 44	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
DITCHER 44	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
ROW CULT. 44	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
SPRAYER	25.00	0.127	750.0	1.257	0.595	0.001	0.118	2.112	3.409	0.0	0.0	3.409		
DITCHER 44	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
AMMY APPLIC.	12.00	0.257	1200.0	2.214	0.215	0.009	0.232	3.651	3.198	0.0	0.0	3.198		
FORAGE HARVESTER	10.00	0.300	3325.0	2.773	0.775	0.034	0.326	10.914	2.822	0.0	0.0	2.822		
751 CELL D-125	3.00	0.500	2370.0	1.050	0.510	0.035	0.399	2.236	3.100	0.0	0.0	3.100		

out. This scale is reached at about 1,000 tons, regardless of the acreage or yield per acre involved. Costs developed for these operations (from standing crop to loaded highway truck) are of the order of \$11 to \$12/ton (1974-1975 basis). Legitimate exceptions to the general mowing-raking-baling method can be proposed for certain crop residues. For example, wheat combining operations harvest a portion of the crop residue, and the straw can be left in the field in windrows suitable for baling. The same consideration applies to the hay component of grass seed harvest, where approximately 50% of the residue is harvested by the grass combine.

A cost question of particular significance with regard to crop residue costs involves a charge for land ownership. This question does not lend itself to a ready resolution. A second cost item which must be considered is a management cost for crop residue harvest. Initial tendencies in this connection are to view the crop residue as a "pure by-product," i.e., as a product which had no value prior to its consideration as a biomass product; and following through with this reasoning by assessing no land charge or management charge. In other words, costs would be simply the direct costs of harvesting, hauling, and storage. Further thought leads to the conclusion that (1) there will be a management cost, which to be consistent with management costs for grains and hays, should be assessed at 7% of returns; and (2) that an economically viable residue-for-biomass crop will in time increase land values and land costs.

Since the intent of this analysis is structured around the assumption of an existing (at some point in time) biomass for energy industry, as opposed to a developing industry, it has been judged best to assume that the residue component of biomass will have to bear its share of land costs--when viewed in an overall framework which includes both grain and residue as products. In other words, both grain and residue are products, and both share proportionate fractions of the land cost. The cost analysis problem reduces to a determination of a reasonable land cost assignable to the residue. From a broad perspective, the land cost for residue should be developed from a systematic analysis of the probable effect on land values of harvesting and marketing residues for biomass. Such an analysis should be structured around regional economic considerations rather than the farmer. A less sophisticated approach can essentially be based on current crop versus land value relationships, the simplest of which is that a certain fraction of the crop must be set aside (i.e., given to the land owner) to pay for the land. In other words, of the order of 1/3 of total cost from the residue might be specified as the land cost. If this approach is taken, and further if management charges are assessed at 7% of total cost, the land charge would be computed as follows:

$$TC = HC + 0.07 TC + 0.33 TC$$

where:

TC = total cost, excluding return to overhead and risk

HC = costs associated specifically with residue harvest

0.07 TC = management charge

0.33 TC = land charge

If the residue returns nothing to overhead and risk, a harvest cost of \$10/ton translates to a needed gross return of \$16.67/ton; and \$12/ton to \$20/ton. For a return to overhead and risk of 5% of costs, gross returns should be \$17.50 and \$21/ton, for harvest costs of \$10 and \$12/ton, respectively.

One additional factor impacts the cost of crop residues. When a crop residue is left on the land and recycled into the soil, as in most management systems, the residue contributes nutrients to succeeding crops, organic matter for helping to maintain soil organic levels, and protection against wind and water erosion. The value of the residues for these purposes is ill-defined, and varies from region to region. For the purposes of this program, it has been assumed that a certain fraction is left on the land. That left behind ranges from 0.5 to 1.0 ton/acre (for soybeans all the residue is recycled). The selected values are not presented as the final or definitive answer to this question, but rather are considered to be reasonable values which undoubtedly will need to be adjusted by regions and crop, and for specific soils and topographic features within regions. With regard to nutrient value and organic matter values, a cost penalty has been assessed as the cost of replacing nitrogen, potassium, and phosphorus removed in the residue. The cost has been determined from published reports of the nutrient contents of the specific residues (Morrison, 1949) (Miller, 1958) and nutrient costs applicable to 1974 to 1975. The resulting costs are in the \$4 to \$7 range per air dry ton. This cost "penalty" does not apply to hay or forage crops, but rather is included as the normal cost of providing nutrients to such crops and is included in preharvest costs.

For crop residues, the cost items are accordingly as follows:

1. Residue harvesting costs, for mowing, windrowing, baling, loading and hauling to roadside storage, and loading to a highway truck.

2. A storage cost, uniformly set at \$0.12/ton, to provide for use of farm land for this purpose several months of the year.
3. A nutrient replacement, or conservation cost.
4. Land and management costs--those assigned specifically to residues as discussed earlier.

The crop residue is not assessed a cost for preharvest expense, nor for the ownership costs (taxes, insurance, machinery investment) attributable to preharvest or harvest of grain operations.

It has been stated above that costs for harvesting biomass are sensitive to the quantity harvested, i.e., machinery costs are sensitive to magnitude of use in a given season. We have used costs in our analysis for a seasonal use level of 1,000 tons or more. This approach amounts to an assumption that custom harvesting is employed, or alternatively that the individual farmer is operating at a relatively large scale for his biomass crops. With this approach we have avoided the problem of estimating costs for an individual farmer (or for many farmers) who has available perhaps 200 to 400 tons of hay or residue, and cannot use farmer-owned equipment effectively. At the lower outputs, costs per ton can be twice the costs for higher outputs (Rider, 1978).

2. Cost Analysis of Transportation of Biomass:

The general system employed in setting up the overall procedure for harvesting, transporting, and converting biomass to energy forms consists of the following. The eight regions are in most instances sized to have the capability to support conversion plants which process 500 to 3,000 tons/day. The regions thus consist of several counties from which biomass crops are drawn. The conversion plant is sited centrally within the region to minimize transportation costs, with no consideration being given to siting factors such as transportation systems, utilities, water, and location relative to markets. With regard to such factors, it can reasonably be assumed that a near optimum site exists generally within the region, and in about the same general proximity to the sources of biomass as the selected site. Siting analyses to locate the plant optimally relative to the market were considered outside the scope of the project.

The biomass, in bales, is first transported to roadside storage on the farm. For present purposes, no protection from the weather has been provided, an assumption which may need to be analyzed further in wetter regions. From roadside storage, hauling is effected by highway trucks capable of hauling 15 tons at a density of 12 lb/ft³. The

trucks operate essentially year round, but with allowance for slack periods when road or weather conditions interfere. An inventory of biomass at the plant site is developed to provide for bad weather and other contingencies.

A rather simple model is used to estimate the cost of transporting biomass from farm to conversion facility. Transportation cost (dollars/ ton-mile) is found as a function of distance hauled, biomass density, and a number of parameters related to the type of truck used and the operating policy chosen.

The basis for determining transportation costs is a single truck used to haul biomass from a farm to a conversion plant a fixed distance away. The truck may actually be used for hauls of different lengths, but the costs obtained for a particular distance are based on the assumption that the truck is dedicated to a particular length of haul. The assumptions used in the analysis are the following:

1. An integral number of trips are made per day.
2. The truck operator will work no longer than a certain number of hours per day (this limit is called TDAY).
3. The analysis is carried out for a single vehicle.
4. All trips made by the vehicle are of the same distance.
5. The cost of operating the vehicle is independent of the load.
6. The truck is assumed to be fully utilized. That is, the truck is assumed to be used TDAY hours per day. This means that if there is time remaining after a trip, but it is not enough to complete an additional round-trip, the truck is put to other uses. The hourly cost capital therefore assumes that the cost can be spread over a day of TDAY hours, even though the truck may be used for less time each day for a given haul distance.
7. The truck operator receives 1.5 times his base pay for working longer than 8 hr/day.

Notation: The following parameters are used in the calculations:

R = Distance of haul, one way (miles)

VOL = Volume of truck (cubic ft)

DENS = Density of load (lb/ft)
 TDAY = Maximum hours worked per day
 V = Truck speed (mph)
 TIDLE = Idle time (load, unload) per trip (hr)
 NDYR = Number of days worked per year
 CINT = Total interest rate on capital, including taxes
 and insurance
 NYR = Equipment life (year)
 CCAP = Initial cost of equipment
 CSALV = Salvage value of equipment
 TCOST = Tire cost
 TLIFE = Tire life (hr)
 PREPAR = Hourly repair rate based on an annual cost equal
 to 6% of equipment cost
 RFUEL = Hourly fuel rate
 RMAN = Hourly operator rate (includes 25% for supervision).

The outputs of the analysis, including intermediate results, are the following:

COST = Cost/ton-mile
 CTRIP = Cost/trip
 QYEAR = Load hauled/year by a single truck (tons)
 CTON = Cost/ton hauled
 CYR = Annualized cost for single truck operation.

Analysis: Using the notation defined above, the truck capacity is given by:

$$\text{LOAD} = (\text{VOL})(\text{DENS})/2,000 \quad (\text{tons})$$

The time required per trip by the truck is:

$$\text{TTRIP} = 2R/V + \text{TIDLE} \quad (\text{hours})$$

Therefore, the number of round trips which the truck can make per day is:

$$\text{NDAY} = \text{TDAY}/\text{TTRIP} \quad (\text{an integer})$$

The total number of hours worked per year by the operator is:

$$\text{TYEAR} = (\text{NDAY})(\text{NDYR})(\text{TTRIP})$$

The cost of transporting biomass is the sum of the operating cost and the capital cost. On an hourly basis the cost of capital is given by:

$$\text{HCAP} = \frac{(\text{CRF})(\text{CCAP}) - (\text{SFF})(\text{CSALV})}{(\text{TDAY})(\text{NDYR})}$$

where:

CRF = The capital recovery factor

$$= \text{CINT}/(1 - (1 + \text{CINT})^{-\text{NYR}})$$

and SFF = The sinking fund factor

$$= \text{CRF} - \text{CINT}$$

The annual cost is then:

$$\text{CYR} = (\text{TYEAR})(\text{HCAP} + \text{TCOST}/\text{TLIFE} + \text{PREPAR} + \text{RFUEL}) + \text{CMAN}$$

where:

$$\text{CMAN} = (\text{RMAN})(\text{TYEAR}) \text{ if } \text{TYEAR} \leq 2,000 \text{ hr}$$

if $\text{TYEAR} > 2,000 \text{ hr},$

$$\text{CMAN} = (\text{RMAN})(2,000) + (1.5)(\text{RMAN})(\text{TYEAR} - 2,000)$$

The material hauled per year is:

$$\text{QYEAR} = (\text{LOAD})(\text{NDAY})(\text{NDYR}) \quad (\text{tons})$$

The cost/ton-mile is:

$$\text{COST} = (\text{CYR})/(\text{QYEAR})(\text{R})$$

The cost per trip is:

$$\text{CTRIP} = (\text{COST})(\text{R})(\text{LOAD})$$

and the cost per ton hauled is:

$$\text{CTON} = \text{CYR}/\text{QYEAR}$$

Since there is a requirement for an integral number of trips per day and since the driver is paid overtime, the volume of material hauled and the costs are not continuous functions of the distance hauled. However, the discontinuities are relatively small and do not significantly influence the results obtained.

Table 15 shows typical parameter values used. The operator cost includes a 25% cost for supervision. Table 16 shows results based on these input values.

TABLE 15

TRANSPORTATION INPUT PARAMETERS

Truck volume (ft ³)	2,500.0	Load density (lb/ft ³)	12.0
Maximum hours worked/ day	10.0	Truck speed (mph)	30.0
Idle time/trip (hr)	0.5	Number of day/year	250.0
Interest rate (%)	15.0	Truck life (years)	5.0
Capital (\$)	23,000.00	Salvage value	2,300.00
Tire (\$)	3,000.00	Tire life (hr)	2,000.00
Repair (\$/hr)	0.69	Fuel (\$/hr)	3.60
Operator (\$/hr)	12.50		

TABLE 16

TRANSPORTATION COSTS

Distance (miles)	Cost/ Ton-Mile (\$)	Cost/Trip (\$)	Cost/Ton (\$)	Cost/Year (\$)	Quantity of Biomass Hauled/Year/Truck (tons)
5	0.274	20.54	1.37	61,620	45,000
10	0.183	27.51	1.83	55,012	30,000
15	0.153	34.47	2.30	51,708	22,500
20	0.142	42.69	2.85	53,360	18,750
25	0.129	48.40	3.23	48,404	15,000
30	0.137	61.62	4.11	61,620	15,000
35	0.119	62.34	4.16	46,752	11,250
40	0.126	75.55	5.04	56,664	11,350
45	0.108	73.14	4.88	36,572	7,500
50	0.107	80.11	5.34	40,054	7,500

Based on the parameters given in Table 15, the cost of capital per hour is \$2.61. Compared to an operator cost of \$12.50 per hr and total maintenance/operation costs of \$5.79, the capital cost is rather small, about 12% of the total costs. Since capital costs are small, the results are relatively insensitive to capital-costs related values and interest rates.

The costs are also fairly insensitive to allowing the operator to work at an overtime rate. For example, for the case considered above, the cost/ton-mile is \$0.142 for a distance of 20 miles. If the operator can work at most 8 hr/day (no overtime) the cost becomes \$0.132. If the maximum day is 12 hr, the cost becomes \$0.156/ton-mile for the same distance.

The cost per ton-mile is almost inversely proportional to the truck volume, load density, and truck speed. Therefore, the results are rather sensitive to these quantities. For short haul distance, the results are also rather sensitive to the lost time (TIDLE) per trip. For greater distances, as the travel time becomes large relative to the loading and unloading times, this factor becomes unimportant. However, for a 20-mile haul at 30 mph, a 30 min idle time constitutes about 30% of each trip and is therefore still rather significant.

Significant factors relative to transportation are as follows:

*Costs per ton increase, of course, as distance increases. Costs per ton-mile are, however, dependent on distance and increase as haul distance decreases. The increase is a consequence primarily of the increase in the relative amount of time spent in loading and unloading. The longer haul distances do not, as a consequence, pose as severe a penalty as one intuitively predicts.

*Transportation costs, per ton, approach 10% of delivered costs of various biomass crops, at about 35 to 45 miles, while costs per ton of residue or whole plant biomass, excluding transportation, vary by 20 to 25%. Transportation costs will thus in the general sense be a lesser factor in a least cost analysis than are production costs. In other words, a least cost analysis will generally select the least expensive-to-produce biomass crop and haul it as far as 35 to 45 miles rather than haul the more costly-to-produce crop a few miles. Transportation costs, on the other hand, become the predominant least cost factor when production costs for available crops are within a range of about 10% or less.

*Relative to costs of delivered Btu values (inputs to conversion plants) for residues and whole plant crops, transportation costs range from a lower value of about 10¢/MM Btu at 5 miles, to about 38¢/MM Btu at 50 miles. Production costs, before delivery, range from about \$1.40/MM Btu for residues with no land or management charge assessment, to up to \$4.00/MM Btu for whole plant biomass. These comparisons show clearly that transportation cost, while significant, is considerably less of a factor, for a decentralized energy complex, than the biomass production cost.

3. Methodology for Least-Cost Analysis:

A methodology based on the use of a linear programming approach has been developed for analyzing the possible combinations of crops that might be used in a particular region for supplying a conversion process. In essence, information on biomass production and transportation costs, and on crop yields and acreages are first assembled for each geographical region. Constraints related to plant size and type and biomass availability are next defined. A linear programming approach is then used to select the minimum cost set of crops which will satisfy the constraints. The entire procedure has been computerized.

a. Input data: The input information required for the analysis is the following:

1. Biomass costs
 - *Preharvest cost,
 - *Harvest cost,
 - *Storage cost,
 - *Indirect cost, and
 - *Transportation cost parameters.
2. Biomass yields and areas.
3. Data on the geometry of the region.
4. Minimum quantities of biomass that must be left behind in the field for agricultural purposes.
5. An estimate of biomass storage and handling losses.

Development of biomass-related costs is discussed elsewhere. The present analysis considers preharvest, harvest, storage, and indirect costs to be a function only of crop type in a particular region. Transportation costs are determined based on the separation between producing area and plant location. All costs are combined to give a single cost figure for each crop from each geographical area defined within the region. The analysis is based on the total cost of biomass delivered to the plant door.

For each region crop yields and areas are assembled on a county-by-county basis. (The county is generally the smallest area for which such information is available.) Crop yields are used in whatever is the conventional unit for the crop, e.g., bushels for corn and tons for hay. These yields are reported yields, that is, grain yield, in the case of corn. All yields are then converted to available, oven-dry biomass. This step is carried out at the beginning of the analysis and thereafter only available biomass is considered. The following expression illustrates the conversion used:

$$\left\{ \begin{array}{l} \text{Available, oven-dry} \\ \text{biomass (ton/acre)} \end{array} \right\} = \left[\left\{ \begin{array}{l} \text{Reported} \\ \text{yield} \end{array} \right\} * \left\{ \begin{array}{l} \text{Factor to} \\ \text{convert to} \\ \text{tons per} \\ \text{acre} \end{array} \right\} * \left\{ \begin{array}{l} \text{Factor to} \\ \text{convert to} \\ \text{air-dry} \\ \text{weight} \end{array} \right\} - \right. \\ \left. \left\{ \begin{array}{l} \text{Minimum biomass} \\ \text{that must be left} \\ \text{on field (air-dry} \\ \text{weight)} \end{array} \right\} * \left\{ \begin{array}{l} \text{Fraction of} \\ \text{biomass} \\ \text{available} \end{array} \right\} * \left\{ \begin{array}{l} \text{Factor to} \\ \text{convert to} \\ \text{oven-dry} \\ \text{weight} \end{array} \right\} \right]$$

The minimum biomass that must be left behind in the field is that needed for preventing erosion or maintaining soil fertility. It is expressed in air-dry tons of biomass per acre. The term "fraction of biomass available" is included to allow for storage and handling losses. These losses are generally assumed to be 5% of the available material, so this factor is typically 0.95. The expression above may be used to determine available amounts of residue, whole crop, or grain. The third factor on the right hand side of the expression must be consistent with whether the analysis is for residue, whole crop, or grain. If the calculated yield of available biomass for a crop in a particular area is less than some minimum amount, say 0.8 air-dry ton/acre, then that crop is ignored for that area.

For determination of transportation costs, haul distances are needed. The program used allows each of the counties within each region to be divided into as many as 10 subdivisions. If there are 10 counties within a region, then this subdivision allows as many as 100 separate areas to be considered in the analysis. The centroid for each of these areas is then determined. The haul distance is assumed to be the distance from this centroid to the location of the conversion plant. A straight-line route or a route that is the sum of the north-south and east-west separations between centroid and plant can be used. If no subdividing is done, coordinates of the centroids for each county and coordinates for the plant are recorded. Using the straight line or indirect route selected, the haul distance for each county is then determined. This distance is used in the transportation cost algorithm (discussed elsewhere) to find a transportation cost for each county.

If the counties are subdivided, yields are assumed to be the same in all subdivisions within a county. The fraction of the area of each county contained within each subdivision is found by planimetry. Distances and transportation costs are then found for each subdivision. Subdivision of the counties is of most importance when short haul distances are considered. This occurs when small plant sizes are used.

Generally, it has been found that the additional refinement of subdividing the counties does not produce a significant change in the results obtained.

Analysis

The information that has been described up to this point is required to determine the best crop mix to use for a particular region and conversion plant. The inputs to the analysis are basically the total cost per ton of biomass by crop type and origin and the total available biomass by crop type and origin. The problem of determining the crop mix to use may then be formulated as a linear programming problem, in which the objective is to minimize the total cost of biomass delivered to the plant door, subject to certain constraints. The first such constraint is set by the plant size--a minimum quantity of biomass is required to satisfy plant needs. There is also the possibility of a requirement for particular types of biomass to satisfy the plants requirements. Next, there may also be constraints related to the availability of biomass. These constraints must be considered on a region-by-region basis. Constraints such as the following can be included: maintain certain minimum areas for planting certain crops, i.e., do not expand production of other crops without considering a need for minimum areas for such crops; maintain total planted area constant (or increase by a certain amount); maintain certain relationships between quantities of different crops used; and maintain the current crop production pattern.

The output of the analysis is a tabulation of crop area and biomass by county (or subdivision) which will satisfy the constraints specified at the minimum possible cost. The output also provides an average cost breakdown (i.e., portion of cost due to harvesting, transportation, etc.), average haul distances by crop type, and a variety of statistics related to the crop mix used.

If constraints allow the expansion of certain crops at the expense of others, the available yield in these "new" areas is assumed to be the same as under current cropping conditions. If current production conditions are to be maintained, then the available biomass and current areas determine the quantity of biomass available.

The analysis is structured in such a way that a quite general analysis is possible. The primary limitations involve the reliability of the costs used and the definition of the constraints. The analysis carried out may extend from a (technically) trivial study of current cropping conditions (no shifts in production allowed) to a rather complex study involving shifts in crop production, new crops, expanded areas, and constraints on the minimum total biomass that will be considered for particular crop types..

As structured, a single conversion plant is considered in each analysis. The location of that plant must be specified; the location is not optimized. In addition, the analysis is static--no seasonal effects or details within an annual cycle are considered. The analysis makes no attempt to consider economic or other impacts which may result from the use of a predicted "optimum" mix.

An example of least cost analyses, of the Nebraska-Iowa region, for residues and whole plant crops, is presented in Tables 17 through 22. Data for the eight regions are presented in Appendix A. Sequentially, the tables show:

Table 17 presents information on the crops in the region: corn, soybean, wheat, oats, barley, sorghum grain and rye residues; and whole plant sorghum (silage type), corn hay, alfalfa, and clover. The 0.95 availability factor accounts for losses in storage and handling; the oven-dry residue factor is used to calculate oven-dry residue or whole plant weights from reported yield data, and the residue not removed is the quantity left on the field. "Minimum available residue" (0.80) indicates that yields less than 0.8 ton/acre were rejected.

Table 18 presents acres and reported yields for crops in the region.

Table 19 shows distances to conversion plant sites.

Table 20 presents individual and summed costs for the various crops, assuming that they would be selected and delivered to the conversion plant.

Table 21 summarizes the crops actually selected by least-cost analysis for a 500 ton/day plant, distances transported, and quantities of specific crops.

Table 22 summarizes the results of the least-cost analysis.

In brief, the results show that a 500 ton/day plant can be supported, on a least-cost basis, by an area that requires hauling an average of 12.1 miles, and that the minimum delivered cost is \$39.80/ton. Soybean residues were eliminated from consideration prior to conducting the analyses, as was clover. The biomass raw materials selected for least cost are, as expected, crop residues, since a sufficient quantity of the less costly residues are available near to the conversion plant.

TABLE 17

SCENARIO DEFINITION, NEBRASKA-IOWA

BIOMASS PROJECT LINLAK PROGRAM PREPROCESSOR (11/07/78 VERSION)

SCENARIO NEAR TERM ANALYSIS FOR NEBRASKA-IOWA WITH CURRENT CROP PATTERN-RESIDUE
 REGION NEBRASKA-IOWA
 NUMBER OF COUNTIES 11
 NUMBER OF CROPS 12
 COUNTIES SUBDIVIDED NO
 STRAIGHTLINE DISTANCES NO
 MINIMUM AVAILABLE RESIDUE .60 AIR DRY TON/ACRE

BIOMASS REQUIRED: 500.0 OVEN DRY TONS/DAY

CONVERSION FACTORS	CORN	SOY	WHT	OAT	BAR	RYE	HAY	SGG	SGS	CNS	ALF	CLV
TO POUNDS	56.00	60.00	60.00	32.00	48.00	60.00	2000.00	56.00	2000.00	2000.00	2000.00	1.00
OVEN DRY RESIDUE FACTOR	1.10	.86	1.82	2.71	2.28	1.80	.88	.63	.33	.33	.88	.89
AVAILABILITY FACTOR	.95	0.00	.95	.95	.95	0.00	.95	.95	.95	.95	.95	.95
RESIDUE NOT REMOVED (T/A)	1.00	-0.00	.50	.50	.50	.50	-0.00	.50	-0.00	-0.00	-0.00	-0.00

DATE EXECUTED: 08/09/78.

TABLE 18

CROP ACREAGES AND YIELDS, NEBRASKA-IOWA

COUNTY	CRN	SOY	WHT	OAT	BAR	HYE	HAY	SGG	SGS	CNS	ALF	CLV
AREAS (1000 ACRES)												
1 PLYMOUTH	224.9	82.6	.5	46.4	0.0	0.0	6.9	.8	0.0	27.8	21.6	0.0
2 CEDAR	113.4	33.0	.7	51.0	2.7	.2	10.1	3.8	1.5	29.6	40.8	.1
3 DIXON	89.7	29.0	1.0	29.0	.7	0.0	3.8	1.3	.7	9.5	19.0	0.0
4 WOODHURRY	226.7	68.1	.6	26.0	0.0	0.0	4.4	.1	0.0	18.8	16.3	0.0
5 DAKOTA	53.5	23.5	.3	11.9	.2	.1	1.8	1.4	.1	2.9	8.7	0.0
6 WAYNE	90.5	38.5	.7	31.0	.7	.2	2.7	2.8	1.1	16.1	28.0	0.0
7 THURSTON	78.9	34.5	.8	25.9	.4	0.0	5.2	2.1	1.1	8.1	16.5	.1
8 MONONA	161.4	77.8	3.5	11.3	0.0	0.0	2.8	.5	0.0	8.6	8.6	0.0
9 CUMING	123.1	70.0	3.0	20.0	.3	.2	6.1	1.7	.7	18.7	44.5	.1
10 HURT	125.6	76.5	6.6	10.1	.3	.1	3.0	4.4	.2	8.2	17.6	.3
11 HARRISON	157.3	80.9	6.4	14.4	0.0	0.0	2.9	1.9	0.0	8.3	12.2	0.0
YIELDS (AS REPORTED)												
1 PLYMOUTH	66.40	35.6	36.0	65.0	0.0	0.0	1.5	52.3	0.0	10.0	3.2	0.0
2 CEDAR	35.60	21.7	30.1	44.0	40.0	20.0	1.1	42.6	9.0	7.6	2.2	80.0
3 DIXON	37.60	25.2	26.7	52.0	41.0	0.0	1.6	61.4	9.0	7.0	2.3	0.0
4 WOODHURRY	82.90	34.0	34.7	62.2	0.0	0.0	1.5	65.1	0.0	12.1	3.2	0.0
5 DAKOTA	64.20	32.2	32.0	51.0	40.0	20.0	1.5	39.6	9.0	10.0	3.3	0.0
6 WAYNE	55.50	26.1	22.6	64.0	43.0	20.0	1.4	64.0	9.5	9.0	2.8	0.0
7 THURSTON	63.80	29.1	28.4	61.0	40.0	0.0	1.4	65.2	9.8	10.1	2.9	80.0
8 MONONA	83.10	33.4	33.1	57.9	0.0	0.0	1.5	64.3	0.0	10.2	3.2	0.0
9 CUMING	53.90	32.0	28.2	63.0	40.0	20.0	1.5	65.5	9.0	8.4	3.6	85.0
10 HURT	76.20	32.2	29.4	57.0	39.0	20.0	1.5	58.9	9.0	10.4	3.6	80.0
11 HARRISON	84.00	35.2	33.0	54.7	0.0	0.0	1.5	76.1	0.0	11.8	3.2	0.0

TABLE 19

GEOMETRIC INFORMATION, NEBRASKA-IOWA

08/09/78.

NEAR TERM ANALYSIS FOR NEBRASKA-IOWA WITH CURRENT CROP PATTERN-RESIDUE

GEOMETRIC INFORMATION

DISTANCES FROM CONVERSION PLANT TO CENTROIDS OF REGIONS (MILES)

	SUBDIVISION									
	1	2	3	4	5	6	7	8	9	10
1 PLYMOUTH	50.0									
2 CEDAR	66.0									
3 DIXON	41.0									
4 WOODHURY	34.0									
5 DAKOTA	18.0									
6 WAYNE	37.0									
7 THURSTON	8.0									
8 MONONA	34.0									
9 CUMING	34.0									
10 HURT	33.0									
11 HARRISON	70.0									

FRACTION OF COUNTYS AREA IN SUBAREA

	SUBDIVISION									
	1	2	3	4	5	6	7	8	9	10
1 PLYMOUTH	1.00									
2 CEDAR	1.00									
3 DIXON	1.00									
4 WOODHURY	1.00									
5 DAKOTA	1.00									
6 WAYNE	1.00									
7 THURSTON	1.00									
8 MONONA	1.00									
9 CUMING	1.00									
10 HURT	1.00									
11 HARRISON	1.00									

TABLE 20 - COST BREAKDOWN

10/05/78.

NEAR TERM ANALYSIS FOR NEBRASKA-IOWA WITH CURRENT CROP PATTERN-RESIDUE

COST INFORMATION

TRANSPORTATION COST PARAMETERS (07/11/78 VERSION)

TRUCK VOLUME (F-P#3)	2500.000	LOAD DENSITY (PCF)	12.00
MAX HOURS WORKED/DAY	10.000	TRUCK SPEED (MPH)	30.00
IDLE TIME/TRIP (HOURS)	.500	NUMBER OF DAYS/YR	250
INTEREST RATE (PERCENT)	15.000	TRUCK LIFE (YR)	5
CAPITAL COST	23000.000	SALVAGE VALUE	2300.00
TIRE COST	3000.000	TIRE LIFE (HOURS)	2000.00
REPAIR COST/HOUR	.690	FUEL COST/HOUR	3.60
OPERATOR COST /HOUR	12.500	CAPITAL COST/HOUR	2.61

	CRN	SOY	WHT	OAT	BAR	RYE	HAY	SGG	SGS	CNS	ALF	CLV
NUTRIENT REPLACEMENT COSTS PER AIR-DRY TON HARVESTED	7.91	0.00	5.77	7.96	6.34	5.16	0.00	6.05	0.00	0.00	0.00	0.00
STORAGE COSTS PER AIR-DRY TON HARVESTED	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12	.12
PREHARVEST COSTS PER AIR-DRY TON HARVESTED	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	11.97	16.88	7.41	0.00
HARVEST COSTS PER AIR-DRY TON HARVESTED	11.31	0.00	11.31	11.31	11.31	11.31	9.88	11.31	11.31	11.31	9.88	0.00
INDIRECT COSTS PER AIR-DRY TON HARVESTED **	12.81	99.99	11.39	12.85	11.77	10.98	22.64	11.57	22.07	24.64	30.43	99.99
SUBTOTAL WITHOUT TRANSPORTATION COSTS	32.15	101.11	28.59	32.24	29.54	27.57	36.64	29.05	45.47	52.95	47.84	100.11
TOTAL COSTS PER AIR-DRY TON HARVESTED												

PLYMOUTH	37.49	105.45	33.93	37.58	34.88	32.91	41.98	34.39	50.81	58.29	53.18	105.45
CEMAR	40.10	103.06	36.54	40.19	37.49	35.52	44.59	37.00	53.42	60.90	55.79	108.06
DIXON	37.36	105.32	33.80	37.45	34.75	32.73	41.85	34.26	50.68	58.16	53.05	105.32
WOODBURY	36.13	104.09	32.57	36.22	33.52	31.55	40.62	33.03	49.45	56.93	51.82	104.09
DAKOTA	34.64	102.60	31.08	34.73	32.03	30.05	39.13	31.54	47.96	55.44	50.33	102.60
WAYNE	36.66	104.62	33.10	36.75	34.05	32.03	41.15	33.56	49.98	57.46	52.35	104.62
THURSTON	33.77	101.73	30.21	33.86	31.16	29.19	38.26	30.67	47.09	54.57	49.46	101.73
MONONA	36.83	104.79	33.27	36.92	34.22	32.25	41.32	33.73	50.15	57.63	52.52	104.79
CUMING	36.83	104.79	33.27	36.92	34.22	32.25	41.32	33.73	50.15	57.63	52.52	104.79
HURT	35.95	103.91	32.39	36.04	33.34	31.37	40.44	32.85	49.27	56.75	51.64	103.91
HARRISON	39.35	107.31	35.79	39.44	36.74	34.77	43.84	36.25	52.67	60.15	55.04	107.31

** A VALUE OF 99.99 FOR INDIRECT COSTS MEANS THAT THAT CROP IS NOT CONSIDERED FOR BIOMASS
OR THAT NO COST DATA ARE AVAILABLE

TABLE 21

LEAST-COST CROP SELECTION, NEBRASKA-IOWA, 500 TONS/DAY

10/05/78.

NEAR TERM ANALYSIS FOR NEBRASKA-IOWA WITH CURRENT CROP PATTERN-RESIDUE

SUMMARY BY CROP (WEIGHTS ARE IN OVEN DRY TONS)

	1 CRN	2 SOY	3 WHT	4 OAT	5 BAR	6 RYE	7 HAY	8 SGG	9 SGS	10 CNS	11 ALF	12 CLV
ACRES	1445000.	614400.	24140.	277000.	5300.	800.	50100.	20870.	5400.	156650.	233000.	600
ACRES USED	85992.	0.	17080.	25900.	1900.	0.	0.	530.	0.	0.	0.	0
AVAIL. BIOMASS	1621214.	0.	28329.	536154.	8912.	0.	58454.	2003.	15682.	464326.	584806.	0
BIOMASS USED	87962.	0.	19282.	54131.	3242.	0.	0.	383.	0.	0.	0.	0
PERCENT OF REQUIRED BIOMASS FROM CROP	53.3	0.0	11.7	32.8	2.0	0.0	0.0	.2	0.0	0.0	0.0	0
AVE. DISTANCE TRANSPORTED	8.8	0.0	34.8	8.0	28.7	0.0	0.0	38.0	0.0	0.0	0.0	0

TABLE 22

LEAST-COST SUMMARY, NEBRASKA-IOWA, 500 TONS/DAY

MRI BIOMASS PROJECT LENEAR PROGRAM OUTPUT 8/17/78 VERSION

DATE: 10/05/78.

REGION: NEBRASKA-IOWA

SCENARIO: NEAR TERM ANALYSIS FOR NEBRASKA-IOWA WITH CURRENT CROP PATTERN-RESIDUE

OBJECTIVE: MINIMIZE TOTAL COST TO PLANT DOOR

BIOMASS REQUIRED: 500.0 OVEN DRY TONS/DAY

CONSTRAINTS:

NO CHANGES IN CROP PRODUCTION PATTERN.

SUMMARY FOR REGION (ALL CROPS) (OVEN DRY WEIGHTS)

CHOP AREA	2434100. ACRES	AVAILABLE BIOMASS	3319881. TONS
CHOP AREA USED	131402. ACRES	BIOMASS USED	165000. TONS
PERCENT AREA USED	4.6	PERCENT BIOMASS USED	5.0
AVERAGE DISTANCE TRANSPORTED	12.1 MILES		
TOTAL COST	6581412. DOLLARS/YR		

COST BREAKDOWN:

AVERAGE PREHARVEST COST PER OVEN DRY TON	0.000 DOLLARS
AVERAGE HARVEST COST PER OVEN DRY TON	13.381 DOLLARS
AVERAGE NUTR REPLACEMENT COST PER OVEN DRY TON	9.041 DOLLARS
AVERAGE STORAGE COST PER OVEN DRY TON	0.142 DOLLARS
AVERAGE INDIRECT COST PER OVEN DRY TON	14.948 DOLLARS
AVERAGE TRANSPORT COST PER OVEN DRY TON	2.373 DOLLARS
AVERAGE TOTAL COST PER OVEN DRY TON	39.887 DOLLARS

In other words, the more costly whole plant biomass crops (sorghum, corn, alfalfa, and hay) were not selected because it is less expensive to haul residues a longer distance than to haul whole plant crops even the minimum distance. The selected biomass crops were corn stover (87,962 ton/yr); wheat straw (19,282 ton/yr); oat straw (54,131 ton/yr); barley straw (3,242 ton/yr) and a small amount of sorghum grain residue; for a total of 165,000 tons.

This result is essentially repeated for 1,000 and 3,000 ton/day plants, i.e., only the residues are utilized. For the 1,000 ton/day plant, the average distance transported is 20.4 miles, and the delivered cost has increased to \$40.89/ton. At 3,000 ton/day, the average distance is 29.8 miles, and the cost \$42.21/ton. Since the same materials were selected for all three plant sizes, the increase in delivered cost (from \$39.89 to \$42.21) is due to increased transportation costs.

4. Production Costs - Near-Term:

Cost summaries for all the crops included in the analyses are presented in appendix A. The costs are separated in summaries into several items, e.g. preharvest costs, harvest costs, fixed costs, and nutrient replacement costs for residues. Transportation costs are presented for the minimum cost biomass combinations, for conversion plants ranging from 500 to 3,000 OD tons/day.

a. Residues and hay: The least cost production and delivery data for residue plus hay are summarized in Table 23. Since residues are the least costly biomass source, the crops selected by least cost analyses consisted solely of residue for all regions except Texas, in which crop residues were insufficient for the smallest conversion plant (500 tons/day). The least costly residue in all regions is seed grass residue in Oregon, due to the fact that the nutrient replacement cost is nil (charged to the seed) and associated costs are less than for other residues. The relatively small range in production costs (from about \$35 to \$40/OD ton) is a consequence of varying land costs, regional variations in labor, machinery and fertilizer costs, and crop to crop variations in nutrient replacement costs.

Delivery costs range from about \$2.25/OD ton for 500 ton/day plants to \$3 to \$6/ton for 3,000 ton/day plants, but with high delivery costs of about \$8/ton in Texas due to limited supply and long haul distances. Delivery costs are thus 7 to 15% of total costs for biomass delivered to a processing plant.

The cost of a delivered, OD ton of biomass residue ranges from about 1.45 MM Btu for the unique case of seed grass residues, to \$2.60 to \$2.90/MM Btu for other crop residues.

TABLE 23

LEAST COST BIOMASS RESIDUES/HAY

	Costs, \$ Per OD Ton			
	<u>Production</u>	<u>Delivery</u>	<u>Total</u>	<u>Biomass</u>
Arkansas				
500 tons/day	39.22	3.39	42.61	Wheat straw, rice
1,000 tons/day	39.26	3.76	43.01	Wheat straw, rice
3,000 tons/day	39.25	5.83	45.08	Wheat straw, rice
California				
500 tons/day	40.16	2.84	43.00	Wheat straw
1,000 tons/day	40.36	2.84	43.20	Wheat straw, barley, straw, sorghum, stover rice, straw
3,000	40.57	3.60	44.17	Wheat straw, barley, straw, sorghum, stover rice, straw
Georgia				
500 tons/day	35.13	3.89	39.02	Peanut hay
1,000 tons/day	35.15	5.28	40.43	Wheat straw, peanut hay hay
3,000 tons/day	insufficient quantities			
Illinois				
500 tons/day	34.52	4.45	38.97	Corn, wheat, oats, rye
1,000 tons/day	36.27	3.41	39.68	Corn, wheat, oats
3,000 tons/day	37.44	3.05	40.49	Corn, wheat, oats
Nebraska/Iowa				
500 tons/day	37.52	2.37	39.89	Corn, wheat, oats, barley, sorghum
1,000 tons/day	37.67	3.22	40.89	Corn, wheat, oats, barley, sorghum
3,000 tons/day	37.92	4.29	42.21	Corn, wheat, oats, barley, sorghum
Oregon				
500 tons/day	19.08	2.25	21.33	Seed grass residues
1,000 tons/day	19.08	2.90	21.98	Seed grass residues
3,000 tons/day	32.97	4.36	37.33	Seed grass residue, oats, wheat
Texas				
500 tons/day	35.15	8.06	43.21	Hay, sorghum, silage, corn, wheat, oats
1,000 tons/day	insufficient quantities			

The cost of crop residues will seem to the reader to be unexpectedly high, especially if he is accustomed to thinking of the residues as valueless wastes which are free for the harvesting and hauling. It should be emphasized that the cost analysis is based on the point of view that the residues are a commodity rather than a waste. As stated earlier this means that the residues should be assessed real costs associated with their removal. These costs include a nutrient replacement charge, which in broader terms can be called a conservation charge, i.e. the combined costs of supplying removed nutrients and of providing compensation for preventing erosion and moisture losses. In some cases, the latter may require terracing, contour farming, or conservation tillage practices which would be necessary to a lesser extent without residue removal.

The management charge is considered to be a reasonable and real cost. The principal debatable cost is the land charge, but the debatable question is the amount rather than whether or not the charge is justified. With a fledgling biomass residue industry, i.e. before land values have responded to increased revenues, one anticipates that the producer will be willing to harvest and sell residues with essentially no charge for the land. As the industry becomes established, however, revenues from crop residues will increase land values, and the increase will be reflected in increased residue costs.

Another factor which tends to be overlooked is the penalty which accrues from losses on storage and transportation, and from conversion of field weights to an oven-dry basis. The losses from these factors has been conservatively set at 15 to 16%, so that a field-side cost of \$20/ton becomes about \$24/OD delivered ton, and \$30 translates to about \$36, not including transportation costs. Further, the biomass actually transported to the plant is field dry, and transportation costs are thus higher on an oven-dry basis than on a field-dry basis.

The overall impact of these factors on residue costs is substantial, as shown by the following example:

Basic (example) costs:

Harvest: \$12/field-dry ton;

Transportation: \$3/field-dry ton;

Nutrient (conservation): \$7/field-dry ton.

Delivered cost per oven-dry ton, with no costs other than harvest and transportation: \$17.85;

Delivered cost per oven-dry ton with nutrient or conservation cost added: \$26.20;

Delivered cost per oven-dry ton with management charge at 7% of harvest plus conservation cost: \$27.90;

Delivered cost per oven-dry ton with land charge at 33% and management charge at 7%: \$41.25.

The minimum cost analyses resulted in selections of the least costly crop residues based on a combination of production and transportation costs. Accordingly a common selection is the crop residue which occurs in relatively small quantities in the region, with the major crop in the region being utilized in increasing proportions as conversion plant sizes are increased. The minimum cost analysis is thus perhaps somewhat at variance with what might be expected to develop as the market for biomass develops, i.e., it is more reasonable to expect that the development would be structured primarily around the major crop or crops in a region. The biomass distribution for the various regions, as determined by minimum cost analyses, are as follows:

	<u>Residue/Hay</u>	<u>Percent</u>
<u>Arkansas</u>		
3,000 ton/day:	Rice straw	83%
	Wheat straw	17%
1,000 ton/day:	Rice straw	83%
	Wheat straw	17%
500 ton/day:	Rice straw	69%
	Wheat straw	31%
<u>California</u>		
300 ton/day:	Wheat straw	53%
	Barley straw	46%
	Rice/Sorghum	1%
1,000 ton/day:	Wheat straw	75%
	Barley straw	22%
	Rice/Sorghum	3%
500 ton/day:	Wheat straw	100%

	<u>Residue/Hay</u>	<u>Percent</u>
<u>Georgia</u>		
1,000 ton/day:	Wheat straw	1%
	Peanut hay	99%
500 ton/day:	Peanut hay	100%

Illinois

3,000 ton/day:	Corn stover	84%
	Wheat straw	14%
	Oats straw	2%
1,000 ton/day:	Corn stover	57%
	Wheat straw	41%
	Oats straw	2%
500 ton/day:	Corn stover	15%
	Wheat straw	81%
	Oats/Rye	4%

Kansas

3,000 ton/day:	Wheat straw	100%
1,000 ton/day:	Wheat straw	99%
	Barley/Rye	1%
500 ton/day:	Wheat straw	99%
	Barley/Rye	1%

Nebraska/Iowa

3,000 ton/day:	Corn stover	75%
	Oats straw	22%
	Wheat, Barley, Sorghum	3%
1,000 ton/day:	Corn stover	67%
	Oats straw	23%
	Wheat straw	8%
	Barley, Sorghum	2%
500 ton/day:	Corn stover	53%
	Oats straw	33%
	Wheat straw	12%
	Barley, Sorghum	2%

	<u>Residue/Hay</u>	<u>Percent</u>
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Oregon

3,000 ton/day:	Wheat straw	51%
	Seed grass straw	40%
	Oats/Barley	9%

1,000 and
500 ton/day: Seed grass straw 100%

Texas

500 ton/day:	Corn stover	22%
	Hay	32%
	Wheat straw	9%
	Sorghum stover	12%
	Peanut hay	13%
	Other	12%

The principal resource in Arkansas is rice straw, available in quantities sufficient for a 2,070 ton/day plant. The least cost combinations consist of rice straw and wheat straw, with wheat being selected to reduce transportation costs.

The principal resource in California is barley straw (1.4 million tons) and wheat straw (0.8 million tons). Wheat straw is slightly less expensive than barley straw and is selected exclusively for the 500 ton/day plant. For the 500 ton/day plant approximately equal quantities of wheat and barley straw are selected, with sorghum and rice residues supplying approximately 1% of the total.

In the Illinois region, the biomass supplied for the 3,000 ton/day plant is predominately corn (84%), with the remainder coming from wheat and oats straw. The percentage of wheat straw in the feedstock mix increases to 81% for the 500 ton/day plant, reflecting the somewhat lower cost of wheat straw. Corn stover is, however, available in large quantities (sufficient for a 15,000 ton/day plant) and comprises 95% of the available biomass residue. This region in particular exemplifies the case in which a minor crop is perhaps unrealistically selected from minimum cost considerations alone.

The Kansas region is clearly wheat dominated, as 99 to 100% of the least cost biomass comes from wheat straw.

About 75% of the available biomass in the Nebraska/Iowa regions is corn stover, 22% oats straw, and the remainder wheat, barley,

and sorghum grain. The biomass supplied to conversion plants is distributed approximately in proportion to availability, with small quantities of the minor crops being selected in all cases.

Available biomass in Oregon consists principally of wheat straw (695,000 tons) and seed grass straw (392,000 tons), plus 147,000 tons of oat and barley straw. The 500 and 1,000 ton/day plants are supplied exclusively with seed grass residues, while the 3,000 ton/day plant utilizes all the seed grass residue plus 505,000 tons of wheat straw and 94,000 tons of oat and barley straw. The two major crop residues, wheat and seed grass, could furnish 3,500 tons/day, while all crops could furnish nearly 3,800 tons/day.

The Texas region, even with its large area, can supply a 500 ton/day plant only if all the hay crop excluding alfalfa, and part of the sorghum hay is combined with residues from corn, wheat, oats, sorghum grain and peanuts.

The differences in costs of residues are slight, \$1 or less per ton, for regions in which the biomass is available in quantities substantially exceeding 3,000 OD tons/day; and is about \$2.50/ton higher for 3,000 tons/day than 500 ton/day in Arkansas. The greatest differential exists in Oregon, where grass seed residues suffice for 1,000 ton/day plants, but where more costly grain crop residues must be utilized in 3,000 tons/day plants.

The relatively small differences in at-the-farm costs of crop residues are due chiefly to regional differences in fertilizer, labor, fuel, and similar costs, and to differences between crops for nutrient replacement. Peanut hay has a low nutrient replacement cost, corn has a high replacement cost, and grass seed residues are not assessed this cost.

b. Grain: Costs of grain for biomass shown in Table 24 (see Appendix B for further data) exhibit a considerable variation. The differences are due partly to crop-to-crop variations, and partly to differences in cost from region to region. Corn and sorghum grain are generally the least expensive grains, with \$75 to \$80/OD ton delivered being the lower range of costs. Costs of corn are less in the corn belt than in other parts of the country. Costs of wheat on an OD delivered basis range from about \$90/ton in Kansas to \$105 to \$115/ton in other regions. Oats, barley, and rye costs tend to be slightly higher than costs of wheat. It is clear that from the standpoint of both cost and potentially available supply of grain for biomass, corn in the corn belt is favored. Corn production costs in California, under irrigation, are significantly higher than in Illinois or Nebraska/Iowa, and the same holds true for Georgia, where yields are low and fertilizer requirements

TABLE 24

LEAST COST BIOMASS GRAIN, 500 OD TONS/DAY

	<u>Costs, \$ Per OD Ton</u>			<u>Grain</u>
	<u>Production</u>	<u>Delivery</u>	<u>Total</u>	
Arkansas	124.62	5.66	130.28	Wheat, sorghum
California	131.80	2.76	134.56	Corn, wheat
Georgia	130.95	3.27	134.22	Corn, sorghum
Illinois	76.38	2.25	78.63	Corn
Kansas	100.20	2.87	103.07	Wheat, barley
Nebraska/Iowa	89.84	2.54	92.38	Corn, sorghum
Oregon	118.41	3.53	121.94	Wheat, oats
Texas	88.66	5.29	93.95	Corn, sorghum

high. The Georgia and California costs are about \$30/ton higher than in the corn belt.

Grain feedstocks for ethanol production in 500 ton/day plants are supplied in the various regions as indicated below.

In Arkansas rice is the principal grain crop in this region (993,000 tons), excluding soybeans, with smaller quantities of wheat (130,000 tons) and sorghum (37,000 tons) being produced.

The minimum cost feedstock is, however, wheat and sorghum grain, of which nearly 100% is utilized. The 500 ton/day plant would consume 14% of the combined rice, wheat and sorghum production, and only about 5% of the combined production of soybeans and the above grains. A plant of this size would thus not significantly reduce the capability of the region to grow crops for the food market.

The California region produces about 1.36 million tons of corn, wheat, barley, sorghum and rice, with wheat and barley being the major crops. A 500 ton/day plant would utilize 12% of the combined grain crops. Wheat is the principal minimum cost grain, 88% of the total, with the remainder being supplied by corn.

The Georgia region produces 790,000 tons of grain, excluding soybeans and peanuts. Corn is the principal grain, plus small quantities of wheat and sorghum. The minimum cost feedstock includes all the sorghum (13,300 tons) and 152,000 tons of corn. The 500 ton/day plant would utilize about 12% of the total grain crop of the region.

The Illinois region produces about 5.56 million tons of corn, wheat and oats, with corn comprising 97% of the total. The least cost grain is corn, and a 500 ton/day plant would utilize only 3% of the available corn, wheat and oats production. If soybean production is included, about 2.5% of all grains would be utilized. With the high intensity of grain production in the region, a 500 ton/day plant could be supported from a small area, with an average haul distance of 12 miles. As expected, a plant of this size in Illinois would have little impact on production of corn or other grains for food. The Illinois region stands out also from the standpoint of costs of corn, about \$77/OD ton delivered as comprised to over \$100/ton in California, Georgia and Oregon.

About 90% of the minimum cost grain feedstock in the Kansas region is wheat, with the remainder coming from corn and barley. The delivered cost of the grain, \$103/ton, is significantly higher than the cost of corn in Illinois, but is still less than costs of grain feedstocks in other regions. The Kansas region produces about 1.9 million tons of grain; a 500 ton/day plant would utilize about 9% of the total grain crop.

In 1974, a poor year in the Nebraska/Iowa region, total grain production was 2.7 million OD tons, predominantly corn and oats. The minimum cost feedstock consists of all the sorghum grain (30,000 OD tons), and 135,000 tons of corn, with an average delivered cost of \$92/OD ton. The 500 ton/day plant would utilize 6% of all grain excluding soybeans. The cost of the feedstock would be somewhat less in average production years.

The Oregon region produces wheat, oats and barley at high yields, but on relatively small acreages (295,000 acres). The total yield of grain is about 469,000 OD tons, so a 500 ton/day plant would utilize 35% of production. The minimum cost feedstock is primarily wheat (152,000 tons), plus some oats (13,000 tons). The delivered cost is about \$122/OD ton.

The Texas region also produces modest quantities of grain--426,000 OD tons excluding peanuts. Sorghum grain is the principal crop, 82% of the total. The minimum cost feedstock consists of corn and sorghum grain, at an average delivered cost of \$94/OD ton. The average haul distance is high, about 42 miles, so transportation costs, \$5.29/OD ton, are high compared to other regions with the exception of Arkansas.

The results of analysis of the eight regions with regard to utilization of grain show that 6 of the 8 regions could furnish grain feedstocks for energy use, at the 500 ton/day level, without intruding more than about 10% on the capabilities of the regions to furnish feed grains.

Corn is clearly the least costly grain feedstock, but the cost advantage of corn diminishes outside the corn belt. Sorghum is generally competitive with corn in cost. Three small grains--wheat, oats, barley--are next in order of increasing cost, and rice is the most expensive grain. The delivered costs of grain feedstocks accordingly range from about \$5.25/MM Btu for corn to about \$9/MM Btu for rice.

D. Minimum Cost Analysis, Production Plus Conversion

The minimum cost biomass developed for the various regions was used as feedstock for energy conversion plants of the following types and sizes:

Ethanol, grain fermentation, 500 tons/day;

Intermediate Btu gas (IBG), anaerobic digestion,
500 tons/day;

Intermediate Btu gas (IBG), anaerobic digestion,
3,000 tons/day;

Steam (direct combustion), 3,000 tons/day;

Electricity (direct combustion), 3,000 tons/day;

SNG, oxygen blown reactors (OBR), 3,000 tons/day;

Ammonia via OBR, 3,000 tons/day;

Methanol via OBR, 3,000 tons/day;

SNG, anaerobic digestion, 500 tons/day;

SNG, anaerobic digestion, 1,000 tons/day.

Costs for these processes and products were obtained in part from the general literature, but are primarily those developed by Stanford Research Institute under DOE Contract No. EY76-C-03-0115-PA-131, Mission Analysis for the Federal Fuels From Biomass Program (Schooley, 1978). The costs and plant sizes for the various conversion plants, at zero feedstock costs, are presented in Table 25.

The energy content of the biomass feedstocks has been uniformly set at 7,500 Btu/lb dry weight. Data on heats of combustion indicate a considerable variability, even among samples of a given type of biomass. The selected value should accordingly be viewed as an average value.

The efficiencies of converting energy contents of feedstocks into output energies varies from about 21% for electricity from combustion to 77% for steam generation. Intermediate efficiencies are 33% for production of IBG from anaerobic digestion; 30% for production of SNG by anaerobic digestion; 46% for production of ethanol; 63% for SNG production via oxygen blown thermochemical conversion; 49% for ammonia production; and 58% for methanol production. Costs for output energy forms, with no feedstock costs, range from \$1.70/MM Btu for steam to \$11.62/MM Btu for electricity. Comparisons of costs among different forms of output energy are relatively meaningless, since the different energy forms have widely differing values in commerce. One meaningful comparison shows that synthetic natural gas apparently can be prepared for approximately equal costs by anaerobic digestion and thermochemical processes; anaerobic digestion has an apparent advantage over the thermochemical process in that small plants (500 to 1,000 tons/day) can operate at costs comparable to 3,000 tons/day thermochemical plants. However, the thermochemical process recovers slightly greater than twice the energy, in product SNG, than does anaerobic digestion. As will be shown

TABLE 25

CONVERSION PLANT STATISTICS^{a/}

<u>Plant Type</u>	<u>Product</u>	<u>Input</u>		<u>Output</u> <u>MM Btu/Day</u>	<u>\$/MM</u> <u>Btu^{b/}</u>
		<u>Tons/Day</u>	<u>MM</u> <u>Btu/Day</u>		
Anaerobic digestion	IBG	3,000	45,000	15,000	7.36
Anaerobic digestion	IBG	500	7,500	2,500	8.30
Anaerobic digestion	SNG	1,000	15,000	4,530	4.94
Anaerobic digestion	SNG	500	7,500	2,270	5.98
Fermentation	Ethanol	500	-	3,480	5.97
Steam combustion	Steam	3,000	45,000	34,800	1.70
Electric power	Electricity	3,000	45,000	9,600	11.62
Thermochemical, OBR	SNG	3,000	45,000	28,300	4.82
Ammonia via OBR	Ammonia	3,000	45,000	22,000	6.90
				(1,205 tons)	(\$126/ton)
Methanol via OBR	Methanol	3,000	45,000	26,000	6.01
				(470,000 gal.)	(\$105/ton)

a/ The data apply to crop residues or whole plant biomass, with the exception of the ethanol plant, in which grain is the feedstock.

b/ Revenue requirements without feedstock cost.

later, imposition of feedstock costs results in significantly higher costs for SNG via anaerobic digestion.

The results of minimum cost analyses are summarized in Table 26, which presents the range of costs for grain fermentation to ethanol, in 500 ton/day plants, and for the several processes and plant sizes (500, 1,000 and 3,000 ton/day) for conversion of residue or hay feedstocks. In Tables 27 through 36, region-by-region data on the various processes are presented.

The minimum cost data for output forms of energy (ethanol, intermediate Btu gas, SNG, methanol, ammonia, steam and electricity) show widely varying costs which are not readily compared from one energy form to another, or to a lesser extent between processes and plant sizes. Such comparison are most meaningful when present or projected costs of the energy forms as supplied by other sources as used as the basis of comparison. The first general comparison to be made involves comparison of coal costs with biomass residue or hay costs. Here the comparison is clearly unfavorable to grass and grain biomass, which costs out in the \$20 to \$45/OD ton range and has an energy content inferior to most coals.

Anaerobic digestion and thermochemical gasification processes for generation of SNG exhibit costs which are not substantially different, at zero feedstocks costs, with the thermochemical route having a slight advantage. With feedstock costs added, the difference between the two processes increases, since the thermochemical process is more efficient, by a factor of 2.1:1, in converting feedstocks into SNG. Accordingly SNG costs by anaerobic digestion are in the \$14 to \$16/MM Btu range, while SNG costs via thermochemical gasification are about \$9/MM/Btu. The possible advantage from being able to operate small anaerobic digestion units at reasonable processing costs thus diminishes as feedstock costs increase.

The contribution of feedstock costs to costs of final energy forms varies from about 42 to 70% in response to: (1) differing costs with no feedstock costs included; (2) different efficiencies in converting input energy to output energy; and (3) region differences in feedstock costs, as shown in Table 37.

TABLE 26

SUMMARY OF LEAST COST ANALYSES FOR EIGHT REGIONS

<u>Conversion Plant</u>	<u>\$/MM Btu Output</u>	
	<u>Feedstock Costs</u>	<u>Plant Revenue Requirements</u>
IBG-anaerobic digestion, 3,000 tons/day	7.43-8.97	14.79-16.33
IBG-anaerobic digestion, 500 tons/day	4.24 (Oregon) 7.55-8.56	12.54 (Oregon) 15.85-16.86
Ethanol, 500 tons/day	11.47-19.62	17.98-26.13
Steam, 3,000 tons/day	3.28-3.96	4.98-5.66
Electricity, 3,000 tons/day	12.03-14.52	23.65-26.14
SNG, OBR 3,000 tons/day	4.01-4.84	8.83-9.66
Ammonia, 3,000 tons/day	5.17-6.24	12.07-13.14
Methanol, 3,000 tons/day	4.36-5.36	10.37-11.27
SNG, anaerobic digestion, 500 tons/day	4.77 (Oregon) 8.48-9.66	10.75 (Oregon) 14.46-15.64
SNG, anaerobic digestion, 1,000 tons/day	4.92 (Oregon) 8.66-9.68	9.86 (Oregon) 13.83-14.62

TABLE 27

IBG VIA ANAEROBIC DIGESTIONInput: 3,000 ODT/day, 45.0×10^9 Btu/dayOutput: 15.0×10^9 Btu/dayRevenue Requirements (without Feedstock): $\$7.36/10^6$ Btu

<u>Region</u>	<u>Least Cost Biomass (\$/ODT)</u>	<u>Revenue Requirements (\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	8.97	16.33
California	44.17	8.79	16.15
Georgia	insufficient quantity	-	-
Illinois	40.49	8.06	15.42
Kansas	39.32	7.82	15.18
Nebraska-Iowa	42.21	8.44	15.80
Oregon	37.33	7.43	14.79
Texas	insufficient quantity	-	-

TABLE 28

IBG VIA ANAEROBIC DIGESTIONInput: 500 ODT/day, 7.5×10^9 Btu/dayOutput: 2.5×10^9 Btu/dayRevenue Requirements (without Feedstock): $\$8.30/10^6$ Btu

<u>Region</u>	<u>Least Cost Biomass (\$/ODT)</u>	<u>Revenue Requirements (\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	42.62	8.49	16.79
California	43.00	8.56	16.86
Georgia	39.02	7.77	16.07
Illinois	38.97	7.76	16.06
Kansas	37.93	7.55	15.85
Nebraska-Iowa	39.89	7.94	16.24
Oregon	21.33	4.24	12.54
Texas	43.21	8.60	16.90

TABLE 29

ETHANOL VIA FERMENTATION OF GRAIN

Input: 500 ODT/day Grain

Output: 3.48×10^9 Btu/day, 48,000 gal/day EthanolRevenue Requirements (without Feedstock): $\$6.51/10^6$ Btu

<u>Region</u>	<u>Least Cost Biomass (\$/ODT)</u>	<u>Revenue Requirements (\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	126.13	18.39	24.90
California	134.56	19.62	26.13
Georgia	134.22	19.57	26.08
Illinois	78.63	11.47	17.98
Kansas	103.07	15.03	21.54
Nebraska-Iowa	92.38	13.47	19.98
Oregon	121.94	17.78	24.29
Texas	93.95	13.70	20.21

TABLE 30

STEAM VIA DIRECT COMBUSTIONInput: 3,000 ODT/day, 45.0×10^9 Btu/dayOutput: 34.8×10^9 Btu/dayRevenue Requirements (without Feedstock): \$1,70/10⁶ Btu

<u>Region</u>	Least Cost Biomass <u>(\$/ODT)</u>	Revenue Requirements <u>(\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	3.96	5.66
California	44.17	3.88	5.58
Georgia	insufficient quantity	-	-
Illinois	40.49	3.56	5.26
Kansas	39.32	3.46	5.16
Nebraska-Iowa	42.21	3.71	5.41
Oregon	37.33	3.28	4.98
Texas	insufficient quantity	-	-

TABLE 31

ELECTRICITY VIA DIRECT COMBUSTIONInput: 3,000 ODT/day, 45.0×10^9 Btu/dayOutput: 9.6×10^9 Btu/dayRevenue Requirements (without Feedstock): \$11.62/10⁶ Btu

<u>Region</u>	Least Cost Biomass <u>(\$/ODT)</u>	Revenue Requirements <u>(\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	14.52	26.14
California	44.17	14.23	25.85
Georgia	insufficient quantity	-	-
Illinois	40.49	13.05	24.67
Kansas	39.32	12.68	24.30
Nebraska-Iowa	42.21	13.60	25.22
Oregon	37.33	12.03	23.65
Texas	insufficient quantity	-	-

TABLE 32

SNG VIA THERMOCHEMICAL (OBR)Input: 3,000 ODT/day, 45.0×10^9 Btu/dayOutput: 28.3×10^9 Btu/dayRevenue Requirements (without Feedstock): $\$4.82/10^6$ Btu

<u>Region</u>	Least Cost Biomass <u>(\$/ODT)</u>	Revenue Requirements <u>(\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	4.84	9.66
California	44.17	4.78	9.60
Georgia	insufficient quantity	-	-
Illinois	40.49	4.35	9.17
Kansas	39.32	4.23	9.05
Nebraska-Iowa	42.21	4.54	9.36
Oregon	37.33	4.01	8.83
Texas	insufficient quantity	-	-

TABLE 33

AMMONIA VIA OBRInput: 3,000 ODT/day, 45.0×10^9 Btu/dayOutput: 22.0×10^9 Btu/day, 1,205 T/dayRevenue Requirements (without Feedstock): $\$6.90/10^6$ Btu

<u>Region</u>	Least Cost Biomass <u>(\$/ODT)</u>	Revenue Requirements <u>(\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	6.24	13.14
California	44.17	6.11	13.01
Georgia	insufficient quantity	-	-
Illinois	40.49	5.60	12.50
Kansas	39.32	5.44	12.34
Nebraska-Iowa	42.21	5.84	12.74
Oregon	37.33	5.17	12.07
Texas	insufficient quantity	-	-

TABLE 34

METHANOL VIA OBR

Input: 3,000 ODT/day, 45.0×10^9 Btu/day
 Output: 26.0×10^9 Btu/day, 470,000 gal/day
 Revenue Requirements (without Feedstock): $\$6.01/10^6$ Btu

<u>Region</u>	<u>Least Cost Biomass (\$/ODT)</u>	<u>Revenue Requirements (\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	45.08	5.26	11.27
California	44.17	5.16	11.17
Georgia	insufficient quantity	-	-
Illinois	40.49	4.73	10.74
Kansas	39.32	4.59	10.60
Nebraska-Iowa	42.21	4.93	10.94
Oregon	37.33	4.36	10.37
Texas	insufficient quantity	-	-

TABLE 35

SNG VIA ANAEROBIC DIGESTION

Input: 1,000 ODT/day, 15×10^9 Btu
 Output: $4,530 \times 10^6$ Btu
 Revenue Requirements (without Feedstock): $\$4.94/10^6$ Btu

<u>Region</u>	<u>Least Cost Biomass (\$/ODT)</u>	<u>Revenue Requirements (\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	43.01	9.64	14.58
California	43.20	9.68	14.62
Georgia	40.43	9.06	14.00
Illinois	39.68	8.89	13.83
Kansas	38.66	8.66	13.60
Nebraska/Iowa	40.89	9.16	14.10
Oregon	21.98	4.92	9.86
Texas	insufficient quantity	-	-

TABLE 36

SNG VIA ANAEROBIC DIGESTIONInput: 500 ODT/day, 7.5×10^9 BtuOutput: $2,270 \times 10^6$ BtuRevenue Requirements (without Feedstock): $\$4.98/10^6$ Btu

<u>Region</u>	Least Cost Biomass <u>(\$/ODT)</u>	Revenue Requirements <u>(\$/10⁶ Btu)</u>	
		<u>Feedstock Component</u>	<u>Total</u>
Arkansas	42.61	9.53	15.51
California	43.00	9.61	15.59
Georgia	39.02	8.72	14.70
Illinois	38.97	8.71	14.69
Kansas	37.93	8.48	14.46
Nebraska/Iowa	39.89	8.92	14.90
Oregon	21.33	4.77	10.75
Texas	43.21	9.66	15.64

TABLE 37

CONTRIBUTION OF FEEDSTOCKS TO ENERGY COSTS,
PERCENT OF TOTAL COST

<u>Product/Process</u>	<u>Percent</u>
IBG, anaerobic digestion, 3,000 ton/day	50-55
IBG, anaerobic digestion, 500 ton/day	48-51
Ethanol, 500 ton/day	64-75
Steam, 3,000 ton/day	66-70
Electricity, 3,000 ton/day	51-56
SNG, OBR, 3,000 ton/day	45-50
Ammonia, 3,000 ton/day	43-47
Methanol, 3,000 ton/day	42-48
SNG, anaerobic digestion, 3,000 ton/day	59-62
SNG, anaerobic digestion, 1,000 ton/day	63-66

Comparisons of final energy costs with baseline costs of the fuel forms yield the following:*

Natural Gas

Base Line (1975)	\$1.88/MM Btu
Thermochemical	8.33-9.66/MM Btu
Anaerobic Digestion	13.83-15.64/MM Btu

Steam

Base Line (1975)	\$3.60/MM Btu from coal
Crop Residues	4.98-5.66/MM Btu

Ammonia

Base Line (1978)	\$120-140/ton
Thermochemical	220-240/ton

* Base line market prices: Chemical Marketing Reporter, January 1, 1979; F. A. Schooley, et al., "Mission Analysis for the Federal Fuels from Biomass Program, Paper presented at the Second Annual Symposium on Fuels from Biomass, Rensselaer Polytechnic Institute, June 20, 1978.

Methanol

Base Line (1978)	\$0.44/gal.
Thermochemical	0.60/gal.

Ethanol, Anhydrous

Base Line (1978)	\$1.19-1.22/gal.
Fermentation	1.26-2.15/gal.

Electricity

Base Line, 1975	\$8.80/MM Btu
Biomass, 3,000 ton/day	24.00-26.00/MM Btu

Intermediate Btu Gas

Base Line, 1985	\$2.70/MM Btu
Anaerobic digestion, 3,000 ton/day	15-16/MM Btu

Comparisons of base line prices for the energy forms generally show a significantly higher cost for energy derived from grass and grain resources. The cost of ethanol, with the least expensive grain (corn), is only slightly higher than current (1978) prices for ethanol; costs of steam from biomass residues and coal are also not greatly different; and methanol from biomass compares reasonably well with current methanol prices. Ammonia from biomass is approximately \$100/ton more costly than 1978 prices for ammonia. Synthetic natural gas from biomass is four to eight times as costly as current natural gas prices, and electricity about nine times as costly as current average prices.

The extent to which energy derived from biomass will be able to effectively compete with competitive energy forms cannot be simply derived from these statistics. The penetration will be a function of increases in costs of competitive fuels. Analysis of this question are beyond the scope of this program, and are being carried out in other programs, notably by Stanford Research Institute.

Assumptions regarding penetration need to take into account the effects of general inflation in various cost items on agricultural costs, as well as increases in costs not attributable simply to inflation. In this connection it is of interest to examine the impact on costs of biomass energy of the use of fuels and nitrogen fertilizers derived from biomass. An increase in cost of ammonia of \$0.05/lb (\$100/ton) translates to an increase in cost of biomass of about \$2.50/ton, assuming 200 lb

N/acre and 5 OD tons/acre. Doubling the cost of fuel, i.e. if methanol were substituted for gasoline, would add over \$1/ton. The resultant increase of \$3.50-\$4.00/ton would translate to an increase in energy costs of \$0.70 to \$0.80/MM Btu for a conversion process operating at 33% efficiency.

IV. ANALYSIS OF MID-TERM CROPPING SYSTEMS

A. Introduction

Grass and grain biomass may in principle be derived from either the available feedstocks produced under the present agricultural system, or from a significantly modified production system in which the land resource devoted to grasses and grains is expanded. The better management practices may be more uniformly applied to improve yields and thus supply a greater incremental excess of grass and grain basis available for energy use; or perhaps from regional production systems where the primary emphasis is energy production. In all these possibilities, it is clear that a more effective, intensive use of the available land resource is a requirement.

This portion of the report presents results of analyses of mid-term possibilities for significantly modified cropping systems structured to more effectively utilize the land resources and productive capabilities in regions previously designated--portions of Georgia, Texas, and Nebraska/Iowa.

Mid-term as defined in this program represents the time span in which one might expect to implement biomass agricultural production based on perhaps one step forward in the application of improved management practices, shifts in crops grown, and more intensive land use. Mid-term implies the use and application of production technology, including crop species, which are reasonably well established.

A time span of perhaps 10 years is reasonable from the agricultural technology standpoint, although the numerous parameters involved in coordinating the development of an overall energy system--agricultural production, transportation, energy production, and energy marketing--would appear to preclude this short a time span. One of the more important factors is the cost of energy derived from grass and grain biomass in relation to costs of other energy sources. A second important factor is the capability of a given agricultural region to provide sufficient quantities of biomass feedstocks to support an energy facility sized to make a viable, worthwhile impact on the energy supply picture.

The near-term grass and grain production systems developed for the eight regions (portions of Kansas, Oregon, California, Texas, Georgia, Illinois, Arkansas and Nebraska/Iowa) are geared to current crop production systems. These obviously are not aimed at biomass production per se. Their primary focus is on grain crops and forage crops (the fiber crops, tobacco, fruits and vegetables are not included in the analysis),

in other words on production of food for animal and man. As the near-term analyses show, crop residues are usually produced in significant quantity and would be a lower cost source of biomass for energy than the current array of whole plant biomass crops--essentially the forages. The current forage crops are fairly diffusely distributed throughout the United States, and in addition are not actually available to an energy industry. The crop residues, i.e., residues from wheat, corn and other grains are limited in potential supply by the acreages of these crops demanded by the food market. While the potential for utilizing crop residues need not be discounted as an energy source--given a favorable economic match between production and energy conversion and use costs--it is evident that one should look beyond both the current or foreseeable grain demand and possible modest intrusions into the present forage crop system for grass and grain derived biomass. Otherwise, one will be limited to a few quads of energy from this resource, which suffers from an added disadvantage because of its relative diffusivity.

There are basically three options available for enhancement of grass and grain production. The first essentially consists of bringing more land in a given region into production, with the added acreage being devoted to biomass production. The added acreage could be devoted to either a grain crop-residue system or to a whole plant-forage type crop, or to combinations of both. In the national sense one would not propose a significant increase in grain crops simply to generate more energy-bearing residues. However, a regional increase in grain crop production can be proposed, with the obvious implication that compensating reductions in grain crop acreages would be effected in other parts of the country. Indeed, if the economic incentives to produce the somewhat less costly residues are favorable, a foreseeable development is a region-by-region increase in acreages of grain crops--with regional increases occurring in response to a demand for residues created by an energy complex located within or near to the regions.

A second option consists of modifying the grain crop/forage crop mix in a given region to emphasize those crops which either yield the greater quantities of available biomass or produce biomass at lesser cost. This option could make greater quantities of biomass available in the regional sense, with an impact on total cost due to reduced transportation costs. With such an approach, soybeans would tend to be shoved aside, since soybean residues are judged not to be available; wheat, corn, and rice would be emphasized, and sorghum grain would be in disfavor because of the low residue yield. In limited regions, peanut hay residue would be favored--for its reasonable yield and cost. We do not deem it appropriate to consider an expansion of other small grains--rye, barley, oats--for the reason that a few million added acres of these would seriously disrupt the supply and demand picture.

A third option consists in principal of very markedly changing the production system in a given region. In this option one might, for example, envision large acreages of the Georgia region as being dedicated extensively to perennial grasses, with assumption of management practices aimed at higher yields; or institute a similar approach for the Nebraska/Iowa region. With regard to the Nebraska/Iowa region, it is within the realm of possibility to nearly double corn acreages, with the intent of harvesting residues and excess grain as biomass.

Implied in the above approaches to altering current cropping practice is the possibility that one might significantly modify the region-to-region distribution of grain and grass crops. In practice, such redistributions would occur if the relative economic merits of food versus energy crops were to differ significantly from region to region. It is possible that the Georgia region, for example, could compete more effectively with an energy crop than with a food crop. Given a favorable economic situation for an energy crop, substantial acreages in Texas might tend toward an emphasis on energy, from the present mix of rangeland and agricultural crops.

Before proceeding to discussions of specific mid-term scenarios, it is in order to put into perspective the nature and extent of the land resource available for grass and grain production. As indicated in the Phase I report, only about 20% of the land area in the 48 states is classified as cropland. Of this 20%, slightly more than one-half is actually in cultivated crops--the remainder is essentially in reserve as fallow land, temporary pasture, land in conservation programs, or is temporarily idle. Production at any one time is in general terms on the better land, so that the remainder is inherently less productive and can be expected to have certain limitations in projected usage for biomass production. Another 20% or so is private rangeland, so designated because it is not needed for cultivated crops, does not fit the pasture designation, and is usually limited in production capabilities because of sparse rainfall. A substantial fraction of the rangeland could be quite productive given higher rainfall.

A third major category of land is forestland. Land in this present use has not been considered as a resource for grass and grain crop production, although a large acreage could in principal be cleared and be made productive for grasses.

The so-called marginal land considered as potentially available for grass and grain biomass production thus excludes forestland, and includes fringe land presently in pasture, range, cropland reserve, and idle reserves. The U.S. Department of Agriculture has classified land in these general categories in terms of capabilities and limitations for

agricultural use. The land classes so developed have descriptors which indicate whether the soil or land is limited by erosion problems, soil problems, water problems, or climate problems. In order to derive a more definitive description of what might be grown on such lands, it is necessary to look at factors such as specific types of soils, topography, and like factors. In general, it could be concluded that land with an erosion problem can be cultivated if proper means are taken to control erosion. A climate problem generally can be considered to be unresolvable unless water can be provided artificially. A soil problem does not preclude use, but may if the soil is too shallow or stony or has other problems of a mechanical or chemical nature which seriously limit production. Land with a water problem can in principal be considered for use with water-tolerant plants, although problems associated with its use may be substantial in some cases.

In spite of the fact the acreages which fall under the above definition of marginal land are several hundred million acres in magnitude, there remains the question of actual availability for use for biomass production. Land under private ownership is nearly always put to some productive use, and substitution of another use (in this case energy production) will hinge on a combination of economics, tradition, and the priority issue--food versus another basic product, with perhaps an overtone of ecology and environmental qualities. The tenor of the evaluations conducted under this program is based primarily on the assumption that the land will become available if economic factors favor the new use, and further, that upgrading of overall crop and land management practices will occur if the demand is real and based on attractive economic terms. Such a hypothesis should apply equally well to a region now intensive in agriculture as well as to one which presently has limited agriculture. However, changes which involve serious intrusions into a major segment of a region's production mix, i.e., livestock production, will not occur readily, and modified production systems will be better accepted and more readily implemented if these can still be accommodated within the modified framework.

Mid-term cropping systems have been developed in this study for the Nebraska/Iowa region, the Georgia region, and the Texas region. The remaining regions were not considered in depth. The Illinois region is presently very intensive in corn and soybeans. Little land is available in the marginal or underutilized categories, and it does not seem appropriate to suggest changes which would disrupt the basic pattern in the region. The Arkansas region is fairly intensive in agriculture, and acreages which might be available for biomass are mostly forestlands. The Oregon region is unique and heavily committed to grass seed; the grass seed industry is a source of substantial biomass at reasonable cost. The California region depends heavily on irrigation, and produces a diversified mix of crops which in principle could be displaced with

irrigated biomass crops, a possibility which we have elected not to consider in depth.

The Nebraska/Iowa region is generally representative of a Midwestern corn-soybeans-livestock area, with agriculture fairly extensive at present but with opportunities to both expand land usage and improve production capabilities by implementation of the management practices which seem reasonable and achievable--and which should be put into practice if the demand for biomass production materializes.

The Georgia region in the overall sense is underdeveloped and underutilized, and comes forth as a region with good potential to expand into and contribute substantially to energy production.

The Texas region is similar to the Georgia region in that large acreages are in principal suited to biomass production and are presently underutilized for crop production. Texas differs from Georgia, however, in its moisture resource, and thus is a candidate for evaluation of the large area--lower yield dryland system, or given the availability of irrigation production of irrigated biomass crops.

B. Mid-Term Cropping Systems, Nebraska/Iowa Region

The five major agricultural commodities in the region are corn, soybeans, oats, livestock forage crops, and livestock, with a smattering of wheat, sorghum grain, and barley. The grain and forage crops are harvested from about 2.8 million acres out of a total of 3.868 million acres classified as Land Classes 1 through 6e. Thus, about 1 million acres are devoted to grassland (pasture) or are idle for various reasons. The livestock industry supports dairy and beef cow herds of about 250,000 head, and about 750,000 head/yr of cattle are finished for the beef market. Hogs are an important commodity, but hog statistics have not been accumulated since hogs have a lesser impact on biomass availability than cattle.

The mid-term cropping systems developed for the Nebraska/Iowa region are based on five premises:

1. That changes from the present system are consistent with good land conservation practices. The cropping systems accordingly include conservation practices which protect the productive capability of the land and are sensitive to environmental issues, i.e., unnecessary soil loss and the accompanying pollution problems.

2. That the current agricultural production system is not significantly modified in the sense that corn, forage crops, and soybeans are still the major crops, and that the region maintains its livestock production capabilities.

3. That the crops are essentially those already known to the region.

4. That improved management practices are implemented so that the yields per acre can be increased relative to those at present. This premise should be viewed in the context of an improvement which is reasonable and will follow naturally if the demand for products is real and has an attractive economic incentive, rather than as a reflection on current management practice.

5. That a more intensive use of the available land resource can be accomplished. Thus, the modified systems include production of varying types from the entire 3.868 million acres in Land Classes 1 through 6e.

The current system in the Nebraska/Iowa region is described briefly below to provide a background for the modified cropping systems.

Approximately 1.5 million acres is devoted to corn grain. At an average yield of 87 bushels/acre, the total yield is about 2.3 million oven dry (OD) tons of grain, valued at about \$315 million.

Soybean production on 615,000 acres yields about 600,000 tons of beans valued at \$90 million.

Oats production on 277,000 acres yields 230,000 OD tons of grain valued at \$24 million.

Silage production on approximately 100,000 acres yields 400,000 OD tons valued at \$18 million.

Hay production on 285,000 acres yields 645,000 OD tons valued at about \$34 million.

Wheat, barley, and sorghum grain produced on 50,000 acres total to 60,000 OD tons valued at \$6 million.

Total forage needs (hay, silage, and pasture) for the livestock industry are estimated to be 2 million OD tons annually. Accordingly, about 950,000 tons must be derived from pasture, grain crop after-grazing, oat or barley straw, or from imports. If this demand is assumed to be supplied internally, its value is about \$45 million.

These data sum to be a total of 6 million tons of OD biomass valued at \$532 million.

The current production system could deliver about 3.15 million OD tons of crop residue annually, or 9,550 tons/day. The hay is not available for energy use, nor is a considerable fraction of the grain since the grain supports the livestock industry. In analyses presented later, it is assumed that specific quantities of grain and hay are placed in reserve for food and livestock uses, in order to assess what excess quantities would be available for biomass/energy use. Two values for grain reserves have been set: 4 million OD tons annually, which is approximately present production; and 3 million tons, which is about 10% higher than grain produced by the modified cropping system least intensive in grain. The forage reserve is 2 million OD tons. Thus, all harvestable, available biomass (i.e., in excess of quantities left on the field: 1 ton field dry (FD) residue per acre for corn; 0.5 tons/acre for other grains; no soybean residue removed) in excess of 6 million tons in the one case, and 5 million tons in the other, is considered to be available for energy utilization.

If these criteria are applied to the current production, the data shown in Table 38 result. The current system could provide 2,935 OD tons of corn grain/day at a cost per MM Btu of \$6.66; 9,550 OD tons of residues at \$2.94/MM Btu, or a total of 12,485 tons/day at an aggregate cost of \$3.80/MM Btu. Additional revenues to the farmer from sale of residues at cost (no return to overhead and risk) would be \$120 million, increasing total revenues from \$532 million to \$652 million.

Four mid-term cropping systems were first developed by Dr. W. D. Shrader of Iowa State University, without specific allowance for providing a forage reserve for livestock. These were later modified to provide reserves for silage and for hay production dedicated to cattle. The original cropping systems are designated No. 1 through No. 4; the modified system Nos. 1a through 4a. The basic trend in these systems is as follows:

In system Nos. 1 and 1a, only the gently sloping lands, 5% or less, are placed in cultivated annual crops of specified rotations of corn, soybeans, oats, and meadow. These systems result in considerably reduced acreages of corn and soybeans relative to the present system, and quite large acreages in hay crops.

In system Nos. 2 and 2a, additional acreages are brought into cultivated crop rotations, with conservation tillage specified for the more erodible land (2e and 3e) to minimize erosion. This system is closest to the present system in terms of acreage distribution among

TABLE 38

ENERGY AVAILABILITY AND COSTS, CURRENT SYSTEM,
NEBRASKA/IOWA REGION

	<u>5 • 10⁶ Tons Reserve</u>		<u>Dollars/MM Btu</u>
	<u>OD tons/day</u>	<u>Annual Cost</u>	
	<u>Delivered</u>	<u>10⁶ Dollars</u>	
Corn grain	2,935	96.5	6.63
Crop residues	9,550	139	2.94
Aggregate	12,485	235.5	3.80

	<u>6 • 10⁶ Tons Reserve</u>		<u>Dollars/MM Btu</u>
	<u>OD tons/day</u>	<u>Annual Cost</u>	
	<u>Delivered</u>	<u>10⁶ Dollars</u>	
Crop residues	9,550	139	2.94

various crops, but of course differs from the present way the land is managed.

In cropping system Nos. 3 and 3a, 3e land is terraced to permit use of a corn, corn, soybean (CCSB) rotation.

Finally, in cropping system Nos. 4 and 4a, 4e land is terraced to permit a CCSB rotation.

The rotations employed in the various systems consist of: CCSB; corn, soybean, corn, oats, meadow (CSBCOM); and corn, corn, soybean, oats, meadow, meadow (CCSBOMM). No sorghum grain, barley, wheat, or sorghum silage is specified in the systems. The quantities of these crops are very minor at present, and their retention in the overall crop mix would not significantly affect the results of this analysis.

The hay in the cropping systems is essentially the well-managed hay crops now grown in the region, with alfalfa and brome grass being the basic species.

Yields of corn, soybeans, oats and hay on different land classes for the modified cropping systems are shown in Table 39.

System Nos. 1 through 4 are documented in Tables 40 through 43, and compared to the present in Table 44.

System No. 1, as stated earlier, has a much smaller acreage in grain crops than at present (1,660,000 acres versus 2,388,000 acres), since No. 1 is designed for cultivated crops with normal tillage practices on low-slope land. Accordingly, quite a large acreage is in harvested hay and forage; 2,203,000 acres. System No. 2, in which conservation tillage is assumed, brings approximately 200,000 acres more than at present into grain crops, but still has a large acreage in hay (1,230,000). System Nos. 3 and 4, in which terraces are provided on 3e and 4e land, respectively, result in essentially total domination of the region's agriculture by grain crops. In System No. 4, only the 221,000 acres of 4e land remains in hay, and 3,647,000 acres are in corn and soybeans.

The production figures for system Nos. 1 through 4 are presented in Table 45. Somewhat surprisingly, the total biomass for the four systems are all about the same; at 11.6 to 11.8 million tons. This is due to the fact that leaving 1 ton/acre of corn residues on the land tends to equalize corn and hay yields, and the increasing acreages in soybeans further reduce the average yields per acre as corn and soybeans become more dominant. The total biomass produced and potentially deliverable to a conversion plant from these cropping systems is of the order of 34,000 OD tons/day, 330 days/yr basis.

TABLE 39

YIELD, BY LAND CLASS, NEBRASKA/IOWA REGION

<u>Land Class</u>	<u>Yield, Bushels Per Acre or Ton Per Acre</u>			
	<u>Corn</u>	<u>Soybeans</u>	<u>Oats</u>	<u>Hay</u>
1	105	40	75	4.0
2e	102	40	72	3.8
2s	90	37	55	3.0
2w	102	38	70	3.8
3e	85	35	60	3.3
3s	75	30	55	2.8
3w	80	30	55	3.0
4e	65	25	55	2.4
6e				1.5

Source: W. D. Shrader, Iowa State University

TABLE 40

CROPPING SYSTEM NO. 1, VEGETATIVE CONTROL,
NEBRASKA/IOWA REGION

<u>Land Class</u>	<u>Crop Rotation</u>	<u>Total Acres</u>	<u>Crop Acreages</u>			
			<u>Corn</u>	<u>Soybeans</u>	<u>Oats</u>	<u>Hay</u>
1	CCSB	430,000	287,000	143,000		
2e	CSBCOM	745,000	298,000	149,000	149,000	149,000
2s	CCSB	5,100	3,400	1,700		
2w	CCSB	287,000	191,000	96,000		
3e	Hay	1,237,000				1,237,000
3s	CCSB	13,000	8,700	4,300		
3w	CCSB	334,000	223,000	111,000		
4e	Hay	596,000				596,000
6e	Hay	221,000				221,000
Total		3,868,100	1,011,100	505,000	149,000	2,203,000

TABLE 41

CROPPING SYSTEM NO. 2, VEGETATIVE AND CULTURAL CONTROL,
NEBRASKA/IOWA REGION

<u>Land Class</u>	<u>Crop Rotation</u>	<u>Crop Acreages</u>			
		<u>Corn</u>	<u>Soybeans</u>	<u>Oats</u>	<u>Hay</u>
1	CCSB	287,000	143,000		
2e	CCSB	497,000	248,000		
2s	CCSB	3,400	1,700		
2w	CCSB	191,000	96,000		
3e	CSBCOMM	412,000	206,000	206,000	413,000
3s	CCSB	8,700	4,300		
3w	CCSB	223,000	111,000		
4e	Hay				596,000
6e	Hay				221,000
Total		1,622,000	810,000	206,000	1,230,000

TABLE 42

CROPPING SYSTEM NO. 3, TERRACE 3e LAND,
NEBRASKA/IOWA REGION

<u>Land Class</u>	<u>Crop Rotation</u>	<u>Crop Acreages</u>		
		<u>Corn</u>	<u>Soybeans</u>	<u>Hay</u>
1	CCSB	287,000	143,000	
2e	CCSB	497,000	248,000	
2s	CCSB	3,400	1,700	
2w	CCSB	191,000	96,000	
3e	CCSB	825,000	412,000	
3s	CCSB	8,700	4,300	
3w	CCSB	223,000	111,000	
4e	Hay			596,000
6e	Hay			221,000
Total		2,035,100	1,016,000	817,000

TABLE 43

CROPPING SYSTEM NO. 4, TERRACE 4e LAND,
NEBRASKA/IOWA REGION

<u>Land Class</u>	<u>Crop Rotation</u>	<u>Crop Acreages</u>		
		<u>Corn</u>	<u>Soybeans</u>	<u>Hay</u>
1	CCSB	287,000	143,000	
2e	CCSB	497,000	248,000	
2s	CCSB	3,400	1,700	
2w	CCSB	191,000	96,000	
3e	CCSB	825,000	412,000	
3s	CCSB	8,700	4,300	
3w	CCSB	223,000	111,000	
4e	CCSB	397,000	199,000	
6e	CCSB			221,000
Total		2,432,100	1,215,000	221,000

TABLE 44

CROPPING SYSTEM ACREAGES COMPARISONS, NEBRASKA/IOWA REGION

<u>Crop</u>	<u>Cropping System Acres (1,000's)</u>				
	<u>1974</u>	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>No. 4</u>
Corn	1,445	1,011	1,622	2,035	2,432
Soybeans	615	505	810	1,016	1,215
Oats	277	149	206		
Wheat	24				
Barley	5				
Rye	1				
Alfalfa	234				
Hay	50	2,203	1,230	817	221
Sorghum grain	21				
Corn silage	157 ^{a/}				
Sorghum silage	5				
Total	2,834	3,868	3,868	3,868	3,868

^{a/} The acreage in silage in the current system is higher than the acreage specified earlier; 1974 was a poor corn year, and more than usual was harvested as silage.

TABLE 45

CROPPING SYSTEM SUMMARY, NEBRASKA/IOWA REGIONS^{a/}

	Cropping System			
	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>No. 4</u>
<u>Corn</u>				
Acres	1,011,100	1,622,100	2,035,100	2,432,100
Grain yield, bu	98,800,000	154,130,000	189,200,000	215,000,000
OD residue, tons	2,000,000	3,120,000	3,800,000	4,200,000
<u>Soybeans</u>				
Acres	505,000	810,000	1,016,000	1,215,000
Grain yield, bu	18,600,000	30,000,000	37,000,000	42,000,000
<u>Oats</u>				
Acres	149,000	206,000		
Grain yield, bu	10,700,000	12,360,000		
OD residue, tons	390,000	433,000		
<u>Hay</u>				
Acres	2,203,000	1,230,000	817,000	221,000
OD yield, tons	5,700,000	2,780,000	1,570,000	295,000
Total residue plus "hay"	8,100,000	6,330,000	5,370,000	4,495,000
Total biomass	11,600,000	11,750,000	11,780,000	11,780,000

a/ One ton of corn stover per acre left on field. One-half ton per acre
oats straw left on field. No soybean residues harvested.

The modified cropping system Nos. 1a through 4a, which reserve acreages for silage and forage production, are documented in Tables 46 through 49. The corn silage acreage (125,000 acres) was deducted from the corn/soybean rotation acreages, as were the hay acreages in system Nos. 3a and 4a. Thus, the net result is some reduction in corn/soybeans to accommodate forage needs--the 2 million tons for the livestock industry. Tables 46 through 49 indicate the quantities of available, deliverable biomass from crop residues, hay, and corn grain, with two levels of reserves for food and livestock, namely 5 million and 6 million tons of grain and forage combined. At this point, it should be mentioned that yields in the hay/forage reserved acreages are those specified in Table 39. It is apparent the modified cropping systems will intrude on the present pasture system--in other words, some of the forage hay may need to come from harvested hay rather than from grazing.

The production, cost, and energy data for system Nos. 1a through 4a are shown in Table 50. The two production reserve levels (5 and 6 million tons) are used as the basis for determining biomass availability. When viewed from the standpoint of total available biomass, the four systems do not differ significantly. System No. 1a would provide the largest quantity, 18,600 tons/day, due to the fact that grain quantities are about 10% lower than the specified 3 million tons reserve for grain. With 3 million tons of grain held in reserve, system Nos. 2a through 4a are capable of supplying 17,475 to 17,835 tons/day. With 4 million tons grain held in reserve, available biomass is in the 14,600 through 15,000 tons/day range.

The distribution of the overall available biomass varies from solely residues and hay in system No. 1a (18,600 OD tons/day; 12,000 tons hay, 6,500 tons residue) through a combination of excess grain and crop residues, with no hay, in system No. 4a (10,650 tons residue; 6,825 or 3,945 tons grain depending on amount held in reserve). By way of comparison, the current production (Table 38) could supply 2,935 tons/day of grain and 9,550 tons of residue (total of 12,485), with 5 million tons of biomass held in reserve. The mid-term cropping systems thus are capable of providing 40 to 45% more biomass than the current system when the specified quantities are held in reserve.

The production and cost analysis presented in this section is based on the assumption that all the excess or available biomass is delivered to an energy conversion plant centrally located within the region. Transportation costs have been developed on the basis that the available biomass is distributed throughout the region in proportion to the acreages in production in the individual counties, and the distance each county is from the plant location.

TABLE 46

MODIFIED CROPPING SYSTEM 1a, NEBRASKA/IOWA REGION

<u>Crop</u>	<u>10³ Acres</u>	<u>Yield, 10³ tons</u>	
		<u>F D</u>	<u>O D</u>
Corn Grain	886.1	2,410	2,120
Corn Residue			1,860
Corn Silage	125		500
Soybeans	505	558	491
Oats	149	172	151
Oats Residue			400
Hay	2,203	6,410	5,700

Available Biomass

	<u>O D tons, 10³</u>	<u>Delivered O D Tons per day</u>
Grain	- none -	- none -
Residue	2,260	6,500
Hay	4,200	12,100
Total	6,460	18,600

TABLE 47

MODIFIED CROPPING SYSTEM 2a, NEBRASKA/IOWA REGION

<u>Crop</u>	10^3 <u>Acres</u>	<u>Yield, 10^3 tons</u>	
		<u>F D</u>	<u>O D</u>
Corn Grain	1,497	3,960	3,485
Corn Silage	125		500
Corn Residue			3,020
Soybeans	810	900	792
Oat Grain	206	198	174
Oat Residue			445
Hay	1,230		2,780

Available Biomass

	<u>$5 \cdot 10^6$ tons Reserve</u>		<u>$6 \cdot 10^6$ tons Reserve</u>	
	<u>O D tons, 10^3</u>	<u>Delivered O D tons per day</u>	<u>O D tons, 10^3</u>	<u>Delivered O D tons per day</u>
Corn Grain	1,450	4,175	450	1,295
Residues	3,465	9,975	3,465	9,975
Hay	1,280	3,685	1,280	3,685
Total	6,195	17,835	5,195	14,955

TABLE 48

MODIFIED CROPPING SYSTEM 3a, NEBRASKA/IOWA REGION

<u>Crop</u>	10^3 <u>Acres</u>	<u>Yield, 10^3 tons</u>	
		<u>F D</u>	<u>O D</u>
Corn Grain	1,776	4,564	4,016
Corn Residues			3,440
Corn Silage	125		500
Soybeans	950	1,030	906
Hay	1,017	2,522	2,246

Available Biomass

	<u>$5 \cdot 10^6$ tons Reserve</u>		<u>$6 \cdot 10^6$ tons Reserve</u>	
	<u>O D tons, 10^3</u>	<u>Delivered O D Tons per day</u>	<u>O D tons, 10^3</u>	<u>Delivered O D Tons per day</u>
Corn Grain	1,922	5,530	922	2,655
Residues	3,440	9,900	3,440	9,900
Hay	746	2,150	746	2,150
Total	6,108	17,580	5,108	14,705

TABLE 49

MODIFIED CROPPING SYSTEM 4a, NEBRASKA/IOWA REGION

<u>Crop</u>	10^3 <u>Acres</u>	<u>Yield, 10^3 tons</u>	
		<u>F D</u>	<u>O D</u>
Corn Grain	2,003	4,982	4,385
Corn Residue			3,700
Corn Silage	125		500
Soybeans	1,064	1,120	986
Hay	676	1,680	1,500

Available Biomass

	<u>$5 \cdot 10^6$ tons Reserve</u>		<u>$6 \cdot 10^6$ tons Reserve</u>	
	<u>O D tons, 10^3</u>	<u>Delivered O D Tons per day</u>	<u>O D tons, 10^3</u>	<u>Delivered O D Tons per day</u>
Corn Grain	2,371	6,825	1,371	3,945
Residues	3,700	10,650	3,700	10,650
Total	6,071	17,475	5,071	14,595

TABLE 50

PRODUCTION, COST, AND DELIVERED ENERGY SUMMARY MID-TERM CROPPING
SYSTEMS NEBRASKA/IOWA REGION

	<u>Hay</u>	<u>Residues</u>	<u>Grain</u>	<u>Aggregate or Total</u>
Cost, \$/ODT	54.50	44.10	99.50 ^{a/}	
Cost, \$/MM Btu	3.63	2.94	6.63	
<u>1a</u>				
ODT/day	12,100	6,500	-	18,600
MM Btu/day	181,500	97,500	-	279,000
\$/year, 10 ⁶	218	94.6	-	313
\$/MM Btu	-	-	-	3.40
<u>2a, 5·10⁶ Tons Reserve</u>				
ODT/day	3,685	9,975	4,175	17,835
MM Btu/day	55,300	149,600	62,600	267,500
\$/day, 10 ⁶	665	145	137	348
\$/MM Btu	-	-	-	3.94
<u>2a, 6·10⁶ Tons Reserve</u>				
ODT/day	3,685	9,975	1,295	14,955
MM Btu/day	55,300	149,600	19,400	224,300
\$/year, 10 ⁶	66	145	42.5	254
\$/MM Btu	-	-	-	3.43
<u>3a, 5·10⁶ Tons Reserve</u>				
ODT/day	2,150	9,900	5,530	17,580
MM Btu/day	32,250	148,500	82,950	263,700
\$/year, 10 ⁶	38.7	144	182	365
\$/MM Btu	-	-	-	4.19
\$/year, 10 ⁶ Inc. Terracing				391
\$/MM Btu Inc. Terracing				4.49
<u>3a, 6·10⁶ Tons Reserve</u>				
ODT/day	2,150	9,900	2,655	14,705
MM Btu/day	32,250	148,500	39,825	220,600
\$/year, 10 ⁶	38.7	144	87	270
\$/MM Btu	-	-	-	3.71
\$/year, 10 ⁶ Inc. Terracing				296
\$/MM Btu Inc. Terracing				4.07
<u>4a, 5·10⁶ Tons Reserve</u>				
ODT/day		10,650	6,825	17,475
MM Btu/day		159,750	102,400	262,000
\$/year, 10 ⁶		155	224	379
\$/MM Btu				4.38
\$/year, 10 ⁶ Inc. Terracing				411
\$/MM Btu Inc. Terracing				4.75
<u>4a, 6·10⁶ Tons Reserve</u>				
ODT/day		10,650	3,945	14,595
MM Btu/day		159,750	59,180	219,000
\$/year, 10 ⁶		155	130	285
\$/MM Btu				3.94
\$/year, 10 ⁶ Inc. Terracing				317
\$/MM Btu Inc. Terracing				4.39

^{a/} Terracing costs for 3a and 4a land not included.

The weighted average transportation distance calculated by this approach is 43 miles, and transportation costs \$0.12/ton mile. On a field dry basis, transportation costs average \$5.15/ton of hay or residue. On a delivered-to-the-plant basis, assuming 5% loss, the cost per OD ton is \$6.10 for hay and residues, and \$4.60 for corn grain, due to the higher density of the grain.

A production cost of \$2.20/bushel was selected for corn grain. On a delivered, OD basis, the cost for corn grain is thus \$99.50/ton.

The road-side cost per FDT of corn residue is \$32.15. With allowances for losses and moisture content, the delivered cost of an ODT is \$44.10. For oats straw, the cost is \$44.20/delivered ODT.

Hay production costs for the different land classes are in the \$40 to \$41 range per FDT. Allowances for transportation, losses and moisture content result in a delivered cost of \$55.10/ODT.

If it is assumed that excess corn grain is harvested with stover in a one-step operation; the cost per ODT delivered is \$68 to \$69, or \$4.55/MM Btu. The cost of handling corn in this manner is less than the costs incurred with separate harvests, where the aggregate cost for grain plus stover is \$74 to \$75/ton.

Mid-term cropping system Nos. 3a and 4a require terracing of 3e and 4e land respectively. Terracing costs are about \$250/acre, and annual maintenance costs 4 to 8% of construction costs (Boehlje, 1979). In system No. 3a, 1,237,000 acres of 3e land is terraced; yields projected for corn are 85 bushels/acre, and for soybeans 35 bushels. In system No. 4a, an additional 326,000 acres of 4e land is terraced; corn yields are 65 bushels/acre, and soybean yields 25 bushels/acre.

Annual costs of terracing without cost sharing or incentives are of the order of \$30/acre. For purposes of this analysis costs to the farmer of \$20/acre are assumed. This cost must be balanced by increased productivity, decreased other costs, increased selling prices, or some combination of these. In the Nebraska/Iowa region, terracing is not accompanied by significant increases in yield. Some reduction in fertilizer needs may occur, due to the greater uniformity of fields, but tillage costs tend to increase since large machinery operates less effectively on terraced land. Benefits do not balance added costs in the short-term, and terracing is justified on the basis of long-term protection of the land resource and the environment, and the overall benefits viewed in a long range perspective.

For the present analysis, it has been assumed that terracing costs are added to other costs, thus increasing production costs by

\$20/acre, or \$30/acre for the corn in a corn-corn-soybeans rotation. If this approach is taken, the biomass production for cropping system No. 3a will be burdened with an added annual cost of \$26,000,000; and system No. 4a will be burdened with an added annual cost of \$32,000,000. If all costs of terracing 3e and 4e land are passed along to the corn grain and corn residues produced specifically on the terraced land, the added costs are \$8.30/ton of grain plus residue, on 3e land, and \$12.10/ton of grain plus residue on 4e land. The additional costs per MM Btu are \$0.55 and \$0.80 respectively, added to \$5.04 and \$5.10/MM Btu for 3e and 4e land respectively. Terracing thus adds 11 to 16% to the cost of delivered corn grain and corn residue biomass.

If terracing costs are allocated to all the available energy biomass produced in the region from system Nos. 3a and 4a, delivered costs increase \$0.30 to \$0.47/MM Btu, or 8 to 10%.

Cost evaluations based on the above considerations are presented in Table 50. The delivered costs for residues, hay and corn grain are \$2.94, \$3.63, and \$6.63/MM Btu, respectively. A conversion plant would likely process hay and residues together, so costs for mixes of these two sources combined will range from about \$3.00 to \$3.50/MM Btu. When corn grain is included in the available biomass, costs range from about \$3.40 to \$4.60/MM Btu; the least cost-maximum quantity energy system would be the residues generated from system No. 4a (10,650 tons/day, \$2.94/MM Btu); this system would also produce quantities of corn and soybeans substantially in excess of current production, for sale through normal channels.

The modified cropping systems developed for the Nebraska/Iowa region serve to illustrate what might reasonably be accomplished in an area now presently fairly intensive in agriculture, by the application of improved management techniques in growing crops and by bringing all the land to a state of productivity commensurate with its capability. As can be seen from the results, the total biomass remains essentially constant as one moves from a grass-dominated to a grain-dominated system, at about 11 million tons per year, or an average of about 2.85 tons/acre/yr. The yield remains constant in spite of the fact that corn produces a higher yield of total biomass per acre than the perennial grass crops, because of the imposed requirement that one ton of corn residues be left on the land. It is true that higher quantities of overall or total biomass could be produced if soybeans were removed from the system, since soybean residues are not counted as being available for energy use. However, elimination of soybeans would be contrary to both the need for this crop and the fact that it plays an important role in the basic crop rotation system for the region.

The data clearly show that the region has the capability of providing significantly increased outputs of energy biomass under the

mid-term cropping systems, without disruption of the ability of the region to provide food grain and maintain the livestock industry. The increases range from the current system capability to provide about 12,500 tons/day of crop residues and excess grain, to a maximum of nearly 19,000 tons/day for system No. 1a (grass dominated). The grain-dominated systems could provide about 17,000 to 18,000 tons/day.

If one elects to assume that all the biomass produced in the region (grain, hay) could be diverted to biomass use, the energy delivered to a conversion plant would be on the order of 32,000 to 34,000 ODT/day, or approximately twice that delivered with the constraint that contributions to the food and livestock industry be maintained. This would have the effect of halving transportation costs for the region's biomass, which in turn would reduce the cost of delivered-to-the-plant energy by about 5%. Some cost benefit would thus accrue to an energy industry if specific regions were dedicated solely to energy biomass production. For the Nebraska/Iowa region the total energy plantation concept would necessitate abandonment of the livestock industry. It would be a matter of considerable difficulty to implement complete dedication to energy production. In the final analysis, a shift of such a magnitude will hinge on economic considerations plus assurance that this energy market will persist.

To put the Nebraska/Iowa region into perspective relative to the energy market, complete dedication of the region to energy would result in support of an energy plant which processes about 20,000 tons coal per day; and the approach which reserves about half the overall production to food and livestock would support roughly the equivalent of a 10,000 ton/day coal-based energy system. Over a 20-year period these figures translate to an equivalent coal reserve in the area of about 135 million tons for the one case, and 67 million tons for the other case.

Over and above costs for producing and delivering certain fractions of the total produced biomass for energy use, it is of interest to compare costs or revenues for the total production systems with one another and with the present production system. As stated earlier, the revenues or value generated from the current biomass produced and consumed within the region are estimated at \$532 million, for 6 million OD tons of grain and forage. In contrast, system No. 1a produces 11.2 million tons of biomass valued at about \$680 million; system No. 2a, 11.2 million tons and \$778 million; system No. 3a, 11.1 million tons valued at about \$807 million; system No. 4a, 11.1 million tons at \$831 million. Delivery of crop residues from the current production system will increase revenues by about \$120 million; system No. 2a (grass-oriented) by \$150 million with delivery of residues and excess hay, and system No. 4a (grain dominated) by \$300 million. Added revenues to the transportation industry will be \$25 to \$35 million.

The above comparisons have not included returns to risk and overhead for crop residues and biomass hay, so the above specified increases are less than expected if a biomass production and energy conversion system were to be implemented on a sound and viable economic base.

The reason revenues increase as one proceeds from system No. 1a to No. 4a is due to the fact that No. 1a emphasizes biomass hay, a lower cost/lower value crop, and No. 4a emphasizes higher cost/higher valued grain crops--corn and soybeans. With respect to delivered cost of biomass, No. 1a is, of course, to be preferred. Also, No. 1a supplies the greater quantity of biomass for energy. It is apparent however, that the farmer will prefer the grain-oriented systems, unless the actual prices commanded by the hay biomass component of his production are adjusted to provide returns comparable to those from the systems dominated by grain.

C. Mid-Term Cropping Systems For The Georgia Region

The Georgia multi-county region contains about 3.4 million acres of land in Land Classes 1 through 4e. Of this land, approximately 1.3 million acres is classified, in the Conservation Needs Inventory, as forestland. The remainder, 2.1 million acres, is classified under the several categories of farmland--row crops, close grown crops, pasture, orchards, conservation use, temporarily idle, hayland, etc. According to mid-1970's statistics, 1.17 million acres is in cultivated/harvested crops, which are principally corn (593,000 acres), soybeans (266,000 acres), peanuts (260,000 acres), and small acreages of wheat (19,000 acres), hay (25,000 acres) and sorghum grain (13,000 acres). There are thus approximately 900,000 acres which, according to the statistics, are underutilized from an agricultural point of view. Any modification of the current production system should reserve at least the current acreage in peanuts. If this is done, 1.84 million acres are in principle available for consideration as a resource for production of the major grain crops--soybeans and corn--of the region, and grass/hay crops or other suitable crops for biomass use. Initial thinking for the Georgia region envisioned kenaf as a biomass/energy crop. The yield potential of kenaf is excellent; however, the root-knot nematode problem is severe with kenaf, and accordingly, we have elected to select a grass crop adapted to the region as the crop of choice. Coastal bermuda grass is an established crop in the region, with good demonstrated yields. Yields in research studies (Burton, 1973) have exceeded 10 tons/acre with heavy fertilization. Hay yields are presently in the 3 to 4.5 ton/acre range, field dry basis. Reasonably achievable yields with relatively modest fertilization rates (200 lb N/acre) are in the 6 to 8 tons/acre range. Therefore, it appears reasonable to project that 6 tons/acre, under uniformly good

management, can be expected. The grass/hay crop has the advantage over annual crops in that organic matter depletion will be a lesser problem, and that preharvest costs are somewhat less due to the perennial character of the grass. Although slopes in the region, for the land classes under consideration, are reported at 5% or less, the perennial crop will still be preferred from the standpoint of erosion control.

Of particular importance with regard to the selection is the fact that bermuda grass is an established crop familiar to the farmer, and more extended use could be implemented more readily than with an unfamiliar crop.

The cropping system which best matches the current system consists of a corn/corn/soybeans/meadow/meadow rotation (excluding peanuts), i.e., 40% corn, 40% meadow, and 20% soybeans. If 1.5 million acres of the 1.84 million "available acres" are placed in these crops, the result is 600,000 acres of corn, 300,000 acres of soybeans, and 600,000 acres of "meadow."

Historically, corn has not been a good yield crop in Georgia, and in other parts of the South. Current management practices, on the average, suffice for 60 bushels/acre or less throughout the southeastern states. Fertilizer requirements per unit of yield are high relative to requirements to the North, as are pesticide requirements. The net result is lower yields at higher costs in the Southeast. For these reasons it would seem appropriate to de-emphasize or perhaps even abandon corn as a significant crop in energy-oriented mid-term cropping systems.

Therefore, two additional mid-term cropping systems have been developed for the Georgia region.

Cropping system No. 2 contains 350,000 acres of corn, 350,000 acres of soybeans, 260,000 acres of peanuts and 800,000 acres of hay.

Cropping system No. 3 has no corn, retains 260,000 acres of peanuts, includes 400,000 acres of soybeans, and places the remainder, 1,100,000 acres, in hay. The biomass for energy from this system consists of hay and peanut hay or residues, for a total of 5,760,000 ODT delivered annually, or 17,450 ODT delivered per day (330 day/yr basis).

Acreage and production data for the three mid-term cropping systems are depicted in Table 51. Biomass data are summarized in Table 52, cost data in Table 53, and biomass availability data in Tables 54, 55 and 56.

Finally, similar data for current production are summarized in Table 57.

TABLE 51

MID-TERM CROPPING SYSTEM NO. 1, NO. 2, AND NO. 3 GEORGIA REGION

<u>Crop</u>	<u>Acres</u>			<u>Yield Per Acre^{a/}</u>	
	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>	<u>Field Dry</u>	<u>Oven-Dry Tons, Delivered</u>
Corn grain	600,000	350,000		70 bu	1.53
Soybeans	300,000	350,000	400,000	30 bu	
Peanuts	260,000	260,000	260,000	3,300 lb	
Corn residue					1.20
Peanut hay					1.42
Hay	600,000	800,000	1,100,000	6 ton	4.90

a/ 5% loss; 1 ton corn residue left on field; 0.5 ton peanut hay left on field.

TABLE 52

MID-TERM CROPPING SYSTEMS NO. 1, NO. 2, AND NO. 3
GEORGIA REGION BIOMASS PRODUCTION

<u>Crop</u>	<u>Total Biomass</u>		
	<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
Corn grain, ODT delivered	980,000	570,000	
Soybeans, field basis, tons	270,000	315,000	360,000
Peanuts, field basis, tons	<u>429,000</u>	<u>429,000</u>	<u>429,000</u>
Total grain, tons	1,679,000	1,314,000	789,000
Hay, ODT delivered	2,940,000	3,920,000	5,390,000
Peanut hay, ODT delivered	370,000	370,000	370,000
Corn residue, ODT delivered	<u>720,000</u>	<u>420,000</u>	
Total hay and residues	4,030,000	4,710,000	6,760,000
Total biomass	5,709,000	6,024,000	7,549,000

TABLE 53

COST DATA, MID-TERM CROPPING SYSTEMS
NO. 1, NO. 2, AND NO. 3 GEORGIA REGION

<u>Crop</u>	<u>Cost per Unit</u>	<u>Total Production Cost</u>		
		<u>No. 1</u>	<u>No. 2</u>	<u>No. 3</u>
Corn grain	2.80/bu	117,600,000	68,600,000	
Soybeans	4.80/bu	43,200,000	50,400,000	57,600,000
Peanuts	11.40/cwt	<u>97,812,000</u>	<u>97,812,000</u>	<u>97,812,000</u>
Total grain		258,612,000	216,812,000	155,412,000
Hay	57.00/ODT delivered	167,580,000	223,440,000	307,200,000
Peanut hay	42.00/ODT delivered	15,540,000	15,540,000	15,540,000
Corn residues	51.00/ODT delivered	36,720,000	21,420,000	
Hay plus residues		219,840,000	260,400,000	322,740,000
Overall		478,452,000	477,212,000	478,152,000

TABLE 54

BIOMASS AVAILABILITY, CROPPING SYSTEM NO. 1
GEORGIA REGION

<u>Biomass Component</u>	<u>ODT/Day</u>	<u>MM Btu/Day</u>	<u>\$/MM Btu</u>
Corn grain	2,960	44,400	8.32
Peanut hay	1,120	16,800	2.80
Hay	8,900	133,500	3.80
Corn residue	2,180	32,700	3.40
Hay plus residue	<u>12,200</u>	<u>183,000</u>	<u>3.64</u>
Overall Total	15,160	227,400	4.55

TABLE 55

BIOMASS AVAILABILITY, CROPPING SYSTEM NO. 2
GEORGIA REGION

<u>Biomass Component</u>	<u>ODT/Day</u>	<u>MM Btu/Day</u>	<u>\$/MM Btu</u>
Corn grain	1,730	26,000	8.32
Peanut hay	1,120	16,800	2.80
Hay	11,900	178,500	3.80
Corn residues	1,270	19,000	3.40
Hay plus residue	<u>14,290</u>	<u>214,300</u>	<u>3.69</u>
Total	16,000	240,300	4.19

TABLE 56

BIOMASS AVAILABILITY, CROPPING SYSTEM NO. 3
GEORGIA REGION

<u>Biomass Component</u>	<u>ODT/Day</u>	<u>MM Btu/Day</u>	<u>\$/MM Btu</u>
Hay	16,330	245,000	3.80
Peanut hay	<u>1,120</u>	<u>16,800</u>	<u>2.80</u>
Total	17,450	262,000	3.74

TABLE 57

PRODUCTION AND COST DATA, GEORGIA REGION CURRENT SYSTEM

<u>Crop</u>	<u>Acres</u>	<u>Production</u>	<u>Production Cost</u> <u>(\$)</u>	<u>ODT/Day</u>
Corn grain	576,000	31,000,000 bu	102,000,000	
Silage	17,000	67,000 ODT	4,000,000	
Soybeans	260,000	6,800,000 bu	34,000,000	
Hay	25,000	67,000 ODT	2,500,000	
Sorghum grain	13,000	540,000 bu	1,300,000	
Peanuts	260,000	8,500,000 cwt	97,000,000	
Wheat	19,000	520,000 bu	2,600,000	
Residues		693,000 ODT ^{a/}	31,800,000 ^{b/}	2,100
Total		2,355,000 tons ^{c/}	275,000,000	

a/ Residue quantities as delivered to conversion plant basis. All other quantities as harvested.

b/ Residue costs include transportation costs.

c/ Field dry basis for grains; remainder oven dry.

Examination of the data in the tables shows that biomass production of grains, residues and hay or forage crops increases from the current production of about 2.3 million tons annually to about 6.5 million tons annually. The increase occurs in response to two factors: (1) bringing more acres into production; and (2) substitution of the higher yielding grass or hay crop for corn. The majority of the increase in total biomass is a consequence of more extensive land use; corn at 70 bushels/acre yields available oven dry residues plus oven dry grain totaling 2.73 tons/acre compared to 4.9 available oven dry tons of hay per acre.

The total cost of production for the current system is estimated at \$275 million, compared to \$477 million to \$478 million for the three mid-term cropping systems, a 74% increase. The average cost per ton of total biomass decreases from \$117/ton for current production to \$84/ton for No. 1, \$79/ton for No. 2, and \$73/ton for No. 3; these average costs include costs for delivery of energy biomass to a centrally located energy conversion plant.

For an energy-oriented production system, the important statistics are those which depict available biomass and its cost. The current system is capable of supporting a crop residue energy plant processing 2,100 ton/day at a delivered-to-the-plant cost of \$3.06/MM Btu. Current corn production would support a 2,200 ton/day energy plant at a delivered cost of \$9.74/MM Btu. System No. 1 would supply 12,200 ODT/day of residues plus hay at an average cost of \$3.64/MM Btu; system No. 2, 14,290 ODT/day at an average cost of \$3.69/MM Btu; and system No. 3, 17,450 ODT/day at \$3.74/MM Btu. System No. 1 could in principle, supply corn grain at 2,960 ODT/day and \$8.32/MM Btu, and system No. 2, 1,730 ODT/day at \$8.32/MM Btu.

Two aspects of the mid-term cropping systems stand out clearly. First, it is possible, by significantly altering land and cropping patterns, to effect a substantial increase in the quantity of biomass which could be produced and made available for energy purposes. The increase is effected in the two cases--system Nos. 1 and 2--without major intrusions into present cropping patterns, and in a third case by eliminating corn as a crop of significance to the region. It is clear that the Georgia region has the potential to significantly increase its contribution to energy production. The second aspect of the mid-term systems is primarily economic. The 70 to 75% increase in gross revenues, on a cost basis, would have a major impact on the agricultural community. If the cost data are revised upward to provide for a reasonable return to overhead and risk, the relative impact would be even greater than the impact which is apparent on a simple cost basis.

It is self-evident that a substantial contribution to energy production in the Georgia region hinges on introduction on a relatively massive scale of crops and a land use pattern which differ substantially from the present cropping system. As pointed out earlier, bermuda grass is a reasonable choice from the standpoint that it is a known crop in this region. This factor would facilitate the transition, which nevertheless would be a major transition involving education of the farmer, an influx of machinery for hay production, and possibly a restructuring of the basic land ownership/farm management pattern for the region. Fertilizer requirements for hay production systems would exceed present fertilizer needs by about 100%. The hay transportation industry would do business on the order of \$30 million to \$40 million annually.

If the farmer/producer is given a reasonable return for his biomass crop, and thus an incentive to produce, there would appear to be little reason to doubt that the cropping systems developed for the region could not be implemented within a reasonable time span, with the principal limiting factor being development of energy conversion systems on a timely basis, i.e., on a schedule which assures a ready market for the biomass as the farmer gears up for production. Unfortunately, hay is not a commodity which stores well without protection from moisture. Also, space requirements for stockpiling will be large, so it is essential that the conversion facility have a capability to accept transition period production and utilize it effectively. Our analysis to the present has not encompassed a systems analysis of the problems and logistics of implementing an energy-producing complex. For an isolated case, it is not likely that implementation of a 1 million-acre biomass production system will overtax the capabilities of the farm machinery and the transportation industries, since 1 million acres is less than 2% of the national acreage in harvested forage crops. The supply of grass seedstock (sprigs) would require some lead time. Fertilizer needs, while large in the local sense, are small in proportion to national use. The major planning activity relative to implementation accordingly revolves primarily around coordination of farm production shifts with provision of a market for the farm product via construction of and bringing into operation the energy conversion system or systems.

The "farm production shifts" alluded to in the previous paragraph are not as simple as purchasing needed equipment, seedstock, and fertilizer, and putting these to their respective uses. Tradition, land ownership and land use patterns, farm size, and farming skill levels all enter into the picture. A large (i.e., corporate) farm is not a requirement, but farms sized for effective use of machinery and other resources is a requirement. The necessary acreages must be made available for continuing production of biomass or for systematic rotation through cropping systems which include biomass. Accordingly, while technical feasibility of the suggested cropping systems (or alternates) may be excellent, success in actual implementation may be difficult to achieve.

D. Mid-Term Cropping System For Texas Region: Guayule

Large acreages of rainfall-deficient land exists west of a line which runs north and south and slightly west of center in Kansas. This land varies markedly in its suitability for agriculture, but much of it is (or would be) quite productive with adequate rainfall or supplemental irrigation. Wheat and sorghums are major dry land crops, and with irrigation, diversified agriculture is practiced. The southwestern portion of the area is a candidate for dry land, cold weather intolerant plants, of which guayule is a recognized candidate. Interest in guayule has focused on its potential for rubber (latex) production, with consideration being given to utilization of latex extraction wastes for fiber or other productive use.

In this study, guayule has been designated as a mid-term crop for evaluation in the Texas region. World War II vintage studies yielded, among other things, a definition of areas suitable for guayule production by virtue of climate, rainfall, soils suitability, and potential land availability. One such area lies within the Texas region, principally in Frio, Zavala, Dimmit, and LaSalle Counties. The total land area designated as suitable is about 1.7 million acres. This area presently is only lightly committed to cultivated crops, and thus perhaps as much as 1.5 million acres could be viewed as available for guayule or other biomass-oriented crops.

A second guayule suitable area is located in Duval, Jim Wells, Live Oak, and McMullen counties. The potentially suitable acreage is smaller than in the Frio-Dimmit-Zavola-LaSalle area, and competition from current crops is more intense. Accordingly, the larger area has been selected for biomass evaluation with guayule or giant reed (Arundo donax).

Guayule requires a minimum of 12 to 15 in. of rainfall annually for reasonable growth, a criterion which the Texas region meets. However, stand establishment is more certain with supplemental irrigation. Guayule propagates by seed, but most of the World War II research involved a nursery seedling transplant operation. To avoid the expense of the nursery approach, this evaluation has been conducted on the basis of field seeding with first-year supplemental irrigation of about 12 in. The cost of irrigation presents somewhat of a problem, since if the irrigation system is set up solely for guayule, the capital costs of an idle irrigation system should be borne by the crop over its life span, which has been set at 20 years. In addition, irrigation resource water is diminishing in quantity and increasing in cost in the region. In this sense, the limited demand for irrigation by guayule is consistent with the resources of the region, in that a guayule production system would not exacerbate the water supply problem and might result in replenishment of the resource.

Two approaches to minimizing the capital burden of an irrigation system can be proposed. The first involves the assumption of a mixed cropping system, with a second crop being irrigated annually during the years when irrigation is not needed for establishing or reestablishing guayule. This approach limits the acreage devoted to guayule and assumes that water supply will be sufficient for continuing irrigation of perhaps 20% of the total area. The second approach assumes a multiyear start-up period for guayule with wells being drilled and made permanently available, but with accessory irrigation equipment being made available on a custom basis, i.e., moved from field to field. The second approach has been selected for this study, recognizing of course that its feasibility and costs would require study and planning. Consistent with this approach is the fact that numerous wells presently exist in the region and would be available for use if a guayule production system were to be started up. The capital cost of an irrigation well, assessed on an annual basis over a 20-year period, is about \$1.00/acre, if one well is used to establish guayule stands on about 640 acres over a 3- to 4-year period. Operating costs, for about 12 in. of water applied during the establishment year, are \$22 to \$23. Fixed costs for irrigation during the establishment year bring total irrigation costs for the year to \$48. Seed costs at \$20/acre, and seedbed preparation, cultivation/pest control, and initial fertilization at \$25/acre, bring initial costs to \$93/acre, a cost which is amortized over a 20-year stand lifetime. Annual maintenance costs are estimated at \$4/acre. Harvest costs are calculated at \$13/ton, with harvest occurring every other year at a yield of 3 tons/acre commencing in the third year. Final harvest for a stand occurs in the twenty-first year for a lifespan yield of 30 tons/acre.

Land value is an item of some uncertainty, since land values in the region are higher than would seem consistent with guayule productivity. A land cost of \$25/acre/yr has been selected; this cost is consistent with crop value. These costs translate to an annual capital cost for the 2-year establishment period of \$15.70/acre, 21-year basis; annual costs (21-year basis) for land, maintenance, harvest, and management of \$49.30; and a total per acre cost of \$65.00. The 21-year cost is thus \$1,365.00 or \$45.50/ton. Transportation costs, based on hauling all biomass produced in the region to a centrally located plant, are about \$3.30/ton. On an oven dry basis with 5% loss, the delivered cost is accordingly \$57.70/ton. At 19-MM Btu/ODT, the cost per million Btu is \$3.04, rounded to \$3.00.

For a 1-million-acre operation, production and cost data are summarized in Table 58.

TABLE 58

MID-TERM CROPPING SYSTEM, TEXAS REGION GUAYULE

Acres devoted to guayule	1 million
Life-span	21 years
Harvested biomass	
Over life-span	30 FD ton/acre 30,000,000 FD tons
Per day (330 d year)	3,660 OD tons delivered 69,540 MM Btu
Cost	\$3.00/MM Btu \$69,700,000 annually

It is well known that considerable interest exists in guayule as a source of latex for the rubber industry. An alternative to the sole use of guayule for energy consists of its production for both markets--rubber and energy. If this approach were to be taken, guayule would first be processed to remove latex, and residues from rubber extraction forwarded to an energy plant. Cost data for rubber extraction should possibly still be viewed as tentative. However, recent cost estimates summarized by Anderson (1978) indicate rubber values will defray a majority of guayule production costs with the by-product energy residues being thus available at reduced cost to the energy industry. The data reported by Anderson are as follows: rubber (latex) extraction costs in the range of 20.5¢ to 28¢/lb; agricultural production costs in the 1980's, 29¢ to 38¢/lb; total rubber costs 49.6¢ to 66¢/lb; and current natural rubber prices greater than 50¢/lb. These data indicate that latex delivered to a latex extraction plant for around 30¢/lb could be further processed at a competitive cost, perhaps even without by-product credits.

The following data and assumptions were employed in assessing a combined latex/energy system based on guayule production.

.Latex yield before extraction: 200 lb/acre, beginning year 3.

.Extraction efficiency, latex: 90%.

.Latex extraction costs: \$0.25/lb.

.Net biomass loss from latex extraction: 12%.

.Latex selling price: \$0.50/lb.

.Cost to handle biomass residue: \$4/ton after latex extraction.

Given these criteria and the costs of producing and transporting guayule to a latex plant, the data in Table 59 are obtained. On an OD basis, the net yield of biomass is of the order of 1 ton/acre.

TABLE 59

COST AND PRODUCTION DATA GUAYULE: COMBINED
LATEX AND ENERGY, 1,000,000 ACRE
SYSTEM ANNUAL BASIS

Field dry tons	1.429×10^6
Latex before extraction (lb)	190.5×10^6
Extracted latex (lb)	171.4×10^6
Biomass available for energy	1.066×10^6 ODT
Guayule production and transportation cost	\$69,700,000
Latex extraction costs	\$42,860,000
Residue handling cost	\$4,260,000
Total cost	\$116,820,000
Revenue from latex	\$85,700,000
Cost, residue, total	\$31,100,000
Cost residue, per ODT	\$29.17
Biomass residue per day	3,230 ODT
MM Btu per day	58,150
\$/MM Btu	1.62

It is evident that guayule as a biomass crop can yield whole plant based energy at a cost which is competitive with the more conventional crops, i.e., \$3.00/MM Btu versus \$3.50 to \$3.80 for grass crops. Part of the advantage of guayule is due to its higher heat of combustion--19 MM Btu/ton compared to 15 MM Btu/ton for grass biomass. The costs calculated on a per ton basis are in fact about \$4.00 higher than for grass. The greatest advantage accrues to guayule, however, from the fact that the latex is a resource of considerable value, a resource which is in an energy product in its own right. The cost assumptions employed in the analysis show that a combined late-energy system yields a biomass residue at a cost of about \$1.60/MM Btu when overall costs are shared with latex manufacture. The one discouraging note in the overall analysis is the fact that large acreages are required for production of a significant quantity of energy--the annual delivered rate is 1.2 tons

of OD biomass per acre if the whole plant is used for energy, and less than 1.1 tons if the latex is first extracted. In principle, large acreages are available for guayule production. It would be an undertaking of considerable magnitude, given the need for limited irrigation, to develop these acreages. On another side of the coin, the guayule production system presented here has the capability of significantly impacting the rubber industry--170 million pounds of rubber is not a small amount in relation to national rubber needs.

Another factor which has a bearing on guayule production is the fact that most of the land in the Texas region is presently vegetated with mesquite. Stand tonnages range from 10 to 50 tons/acre, and the stands must be cleared before guayule can be established. Costs of clearing the mesquite were not included in the cost analysis. It was, instead, assumed that if a biomass industry were in the process of being developed, a market for cleared mesquite would exist, and that this market would more than defray clearing costs, which presently range from \$25 to \$40/acre. Mesquite chipping costs were estimated from costs for wood chipping (Mattson, 1978) at \$10.80/ton, and overall delivered costs, including clearing and transportation, would be of the order of \$16 to \$20/ton depending on stand density and distance transported. This cost range assumes that the mesquite stand is provided at no cost, an assumption which would not be valid if a real market existed for mesquite as an energy crop. In any event, it is reasonable to assume that clearing/ land development costs will not be a penalty to guayule production. Further, the 1 million acres included in the guayule cropping system would provide an inventory of biomass, from mesquite, equal to the biomass produced from guayule in 10 to 15 years.

E. Mid-Term Cropping System For Texas Region: Giant Reed

Giant reed (Arundo donax) is a plant with characteristics which would appear to make it a good candidate as a perennial grass for biomass production in the southern parts of the United States. It develops an extensive root system which gives it good drought resistance, and it thus is a candidate for use in the Southwest where rainfall is a limiting factor. Yields of 8 to 10 tons/acre have been obtained in southern France (France, 1975), where rainfall is of the order of 30 in. annually, but with supplemental irrigation. Fertilizer requirements are modest. Unfortunately, the majority of experience in this country is with limited noncrop applications in the Southwest, where it is used as windbreaks and as embankment stabilizers. The method of establishment involves root cuttings, and 3 to 5 years are needed to establish mature, high-yielding stands. While the literature reports no problems with pests or disease, the limited experience in the United States does not as yet furnish the assurance that such problems will not surface if it is extensively grown. Giant reed is accordingly considered to be an excellent potential biomass candidate, but one sufficiently unknown in

the United States that it is difficult to accurately assess the potential, and to place it in a given situation and accurately predict its response. This uncertainty applies particularly to semi-arid regions of the United States, where large field data are not available. Accordingly, we have elected to assess giant reed under irrigated conditions in the Texas region, deferring the issue of the availability of water for irrigation. Data selected for this evaluation are as follows:

Stand lifetime	20 years
Yield, mature stands	8 FDT/acre
Supplemental irrigation	24 in.
Years to mature stand	4 years
Annual fertilizer cost, mature stands	\$45/acre
Annual operating costs, irrigation	\$45/acre
Establishment cost, years 1-3, excluding fixed irrigation costs	\$275/acre
Fixed irrigation costs	\$27/acre/year
Land cost	
at \$500/acre	\$40/acre/year
at \$700/acre	\$56/acre/year
Harvest costs	\$13/FDT
Management charge	7.5% of total of other costs
Total yield, stand lifetime	143 tons/acre
Average yield per acre, 20 years	7.15 FDT/acre

Analysis of these data yields the following:

.Investment costs for land, irrigation systems, and stand establishment total \$107/acre/year (20-year basis), for land valued at \$500/acre, and \$126/acre/year for land valued at \$700/acre.

.Annual operating costs (including ownership costs for equipment, but excluding ownership costs for irrigation equipment) are \$169/acre (20-year basis).

.Total costs per acre per year, including the management charge, are \$297 and \$317, respectively, for land valued at \$500 and \$700/acre.

.The costs per FD ton are, accordingly, \$41.55 and \$44.33 for the range of land values.

.Addition of transportation costs increases the costs to \$45 to \$48/FD ton. On an OD, delivered basis (including 5% loss) the cost range is \$53 to \$57/ton, or \$3.50 to \$3.80/MM Btu.

A synopsis of cost and production data for 1-million-acre operation is presented in Table 60.

The giant reed production system has the obvious advantage of high yield per acre, and, thus, the capability of supplying a fairly massive biomass feedstock from a relatively few acres. The cost, with irrigation, is about the same as costs for nonirrigated biomass grass crops with 50 to 75% of the yield of giant reed. Since irrigation costs contribute about \$12/ton to OD costs, one might assume, first-hand, that costs would be less by that amount where rainfall is sufficient and irrigation is not needed, e.g., in the Georgia region. However, fertilizer costs would be higher in Georgia, pest control problems could be more severe, and land values should be higher where the investment in irrigation is not needed. The apparent cost advantage will, thus, be eroded in part. Nevertheless, giant reed is a legitimate candidate for the warm climate and higher rainfall areas in the Southeast.

Of particular note is the fact that giant reed production, given the availability of water, generates a large mass of biomass in a fairly small area, i.e., 6 million ODT annually in a 2,700-sq mile area, or about 3.5 tons/acre for the entire area. This figure could be increased by bringing additional acres into production. The Texas region, with giant reed as a major crop, thus represents close to an optimum from the standpoint of minimized transportation costs and a high quantity of biomass feedstock.

TABLE 60

MID-TERM CROPPING SYSTEM: TEXAS REGION
GIANT REED, 1 MILLION ACRES
IRRIGATED, 20-YEAR CYCLE

Yield per acre	
FDT	7.15
ODT delivered	6.05
Annual yield	
ODT delivered	6,050,000
MM Btu	90,750,000
Biomass per day (330 d)	
ODT	18,330
MM Btu	275,000

<u>Cost</u>	<u>Land Value \$500/Acre</u>	<u>Land Value \$700/Acre</u>
Per ODT	\$53.00	\$57.00
Per MM Btu	\$ 3.50	\$ 3.80

V. REGIONAL ECONOMIC ANALYSIS

A. Introduction

This section presents an assessment of the primary economic effects of new market opportunities for existing crops likely to occur in an agricultural region if a biomass conversion plant were to locate in the region and harvest of crop residues (biomass) were economically feasible. As an assessment of the near-term effects of potential biomass harvest, the primary objective of this analysis is to examine the more significant potential consequences of new markets from crop residues, thereby providing a basis for future assessment of the critical planning and policy considerations accompanying establishment of a demonstration biomass conversion plant in any agricultural region of the country.

The decision to define the scope of the regional economic analysis to an overview of critical impact parameters was taken for several reasons. First, in the absence of any past empirical data on the impact of crop residue harvest opportunities in an agricultural region, any quantitative forecasts or projections of economic impact would be highly theoretical. Instead, the broad scope of this analysis will be useful for future methodological development and eventual actual monitoring of regional impacts of a conversion plant.

This approach, it was felt, would lend much greater utility to the study results. Secondly, the selection of the study region to consider in the assessment immediately biases the regional economic analysis, making it difficult to separate those impacts which are specific to the region under study from the more important questions of regional economic impacts in general. To balance this effect, use of the more generalized future scenario approach broadens the frame of reference and thereby avoids some of the regional specificity that would have marginal utility in future policy decisions regarding biomass application. Third, the inherent limitations of any cost data and projections necessitate a very flexible approach to the regional economic analysis. By focusing on the expected probability, direction, and significance of generalized regional impacts, the analysis will continue to be useful as critical data parameters (e.g., cost factors for residue harvest in the region) are refined at a later time.

In summary, the discussion which follows presents a preliminary overview of the selected study region, describes three alternative future scenarios of the region under varying assumptions of the size and influence of the conversion plant, and discusses the probability of selected impacts, both beneficial and adverse, to the economy of a sample agricultural region that could result from new market opportunities to harvest current crops for biomass.

B. An Overview of the Selected Study Region

The selected sample region, an 11-county area in western Iowa and eastern Nebraska (Figure 2), is representative of many agricultural regions of the U.S. in terms of the trends in agriculture which are occurring. Since these trends form the underlying baseline situation against which impacts will be projected, this section presents a general picture of the trends and factors which, in this region as in much of the U.S., are moving agriculture away from the family farm and toward a more concentrated, capital-intensive, and technological industry.

1. Farms, Land in Farms, and Land Use:* In this region, as in the nation as a whole, advances in food and fiber production and processing technologies have meant that increasingly greater investments by farmers in equipment, land, and related means of production have been necessary for farming units to remain cost-effective and competitive. As a result, the number of farms has been declining while the proportion of harvested cropland managed by large production units has increased. At the same time, farmers of this region have been increasing the acreage planted, as cropland previously in cover crops, legumes, and soil-improvement grasses, cropland in summer fallow, and idle cropland have been brought into production. The trends in land use between 1969 and 1974 are shown in Figure 4.** The distribution of cropland between the principal crops of corn, soybeans, oats, wheat, and sorghum is shown in Table 61.

2. Market Value of Agricultural Products Sold: As the total number of farms declines and larger farms plant and harvest increasing acreages of cropland, the market value of agricultural products sold has been rising in this region. Figure 5 shows 1969 and 1974 comparisons of market value for all agricultural products sold, as well as for grain crops and cattle and calves, the two primary categories of agricultural sales in the study region. As land use trends would indicate, sales of grain crops were the largest factor in the 59% expansion of the value of the region's sales of agricultural products. It is interesting to note that three counties, Cuming County, Nebraska; Woodbury County, Iowa; and Plymouth County, Iowa, together contributed over 50 percent of the total market value (1974) for the 11-county region.

* Unless otherwise noted, the data in this section represents farms with sales of \$2,500 or more. (See Figure 3.)

** It should be noted that the situation between 1969 and 1974 reflects several unusual events on world grain markets, including a drought in several regions of the world which raised the nation's export market between 1970 and 1972. As prices for several grain crops increased, previously idle land was brought into production.

Figure 2. Eleven-county sample study region.

SOURCE: USDA, 1974 CENSUS OF AGRICULTURE

Figure 3. For all farms with sales >\$2,500.00: Number of farms, by size and by size of cropland harvest, and total acres harvested in the study region.

Figure 4. Land utilization in the study region.

TABLE 61

1976 PRIMARY CROPLAND DISTRIBUTION IN THE STUDY REGION

	Corn		Soybeans		Oats		Wheat		Sorghum	
	Acres Harvested for Grain	Production (1000 Bu.)	Acres Harvested for Beans	Production (1000 Bu.)	Acres Harvested ^{1/}	Production (1000 Bu.)	Acres Harvested ^{1/}	Production (Bushel)	Acres Harvested	Production (Bushel)
Plymouth, IO	220,600	11,562	79,800	2,144	47,300	2,717	850	25,600	890	45,500
Woodbury, IO	232,800	11,127	60,900	1,513	24,500	1,494	1,280	18,600	850	45,000
Monona, IO	165,600	3,803	75,100	1,687	11,000	640	3,990	121,000	860	49,500
Harrison, IO	168,600	12,628	76,400	2,060	13,300	836	6,300	219,300	2,000	128,300
Burt, NE	115,500	5,233	66,000	1,346	10,500	557	7,400	262,600	4,700	325,600
Cedar, NE	113,500	4,665	27,000	510	46,000	1,564	700	25,200	3,400	158,600
Cuming, NE	112,100	4,752	65,500	1,318	20,000	1,080	2,000	56,000	1,500	92,600
Dakota, NE	55,700	2,797	21,500	430	15,000	645	900	32,300	700	37,100
Dixon, NE	87,000	2,093	21,000	360	31,000	1,333	1,600	54,400	2,300	92,500
Thurston, NE	77,500	2,826	27,000	520	27,500	1,430	1,100	33,000	2,800	197,900
Wayne, NE	87,000	3,686	32,000	514	29,000	1,203	700	17,500	2,700	144,100
Region	1,435,100	75,172	552,200	12,408	275,100	13,526	26,820	885,500	22,700	1,316,700

^{1/} Data for Iowa counties includes only acres harvested for grain.

Source: Nebraska Department of Agriculture, "Nebraska Agricultural Statistics, Annual Report, 1976-1977," Lincoln Nebraska; and Iowa Crop and Livestock Reporting Service, "Iowa Agricultural Statistics, 1977," Des Moines, Iowa.

SOURCE: USDA, 1974 CENSUS OF AGRICULTURE

Figure 5. Increase in market value of agricultural products sold in the study region (by farms with sales of \$2,500 and over).

3. Farm Production Expenses: Farm production expenses in the region of 1969 and 1974 were primarily for purchases of livestock and poultry and their feed. The distribution of 1974 farm production expenses for the region as a whole is shown in Figure 6. While the region's total farm production expenses were dominated by the expenses of Cuming, Plymouth, and Woodbury counties (these three counties accounted for 53% of the total), the proportionate distribution among expenses which is shown in Figure 5, was relatively constant among the 11 counties. Expenses for livestock and poultry were the greatest single category (although down from 1969, when they constituted 44% of the total). Since 1969, purchases for feed, commercial fertilizer, other agricultural chemicals, and gasoline have all increased about 2% relative to total expenditures.

4. Land Values: The 1974 Census of Agriculture does not provide data on county land values. However, a land value survey of May 1975 prepared by the Iowa State University Agricultural Experiment Station indicated average value of farmland in the four Iowa counties which lie within the study region ranged from \$605/acre in Harrison County to \$815/acre in Plymouth County.^{1/} Figure 7 shows the trends in farm land value for selected years between 1967 and 1977 for West Central Iowa, a 12-county region which includes three of the four Iowa Counties in the study area. As shown in this graph, farmland values were continuing to increase in 1977, but at a slower rate than in previous years.

5. Employment and Payroll: As shown in Figure 8, the total number of farms in the study area which hired farm workers declined considerably between 1969 and 1974. The number of farms hiring workers for 150 days or more actually increased, however, a further example of the trend toward larger operations requiring more permanent management and operation of farm business. About 12% of the farms hiring farm workers had 10 workers or more in 1974. Similarly, the total number of workers declined about 12% between 1969 and 1974, but the percent of workers employed 150 days or more increased from 6.3 to 9.7% of the total hired farm labor.

Cash wages paid to hired farm workers in this region increased by over 34% between 1969 and 1974. This indicates that the average wage paid per hired farm worker increased during this period by over 50%, from \$373/worker in 1969 to \$562/worker in 1974.

^{1/} "Farm Land Values Climb Another \$54," Article in Wallaces Farmer, August 9, 1975.

SOURCE: USDA, 1974 CENSUS OF AGRICULTURE

Figure 6. 1974 percent distribution of farm production expenses in the study region.

Figure 7. Average value per acre of farmland in West Central Iowa.

Figure 8. Total number of farms hiring farm workers.

C. Regional Effects of a Market for Biomass Harvest on a Farm Economy

The preceding section examined briefly the major trends in the agricultural region under study, including trends in the number and size of farms, land use, sales, expenses, and employment and payroll of hired farm workers. This section presents an overview of the types of primary economic impacts to the region's farming sector which may occur if biomass harvesting were to become economically feasible.

For purposes of this preliminary assessment, three near-term futures have been considered for the study region. The first scenario follows the assumption that a small biomass conversion plant (500 tons/day) is built in the region, and that for farmers meeting least cost criteria it becomes economically profitable to harvest and sell residues from existing crops. The second and third scenarios assume, respectively, a 1,000 ton/day and a 3,000 ton/day conversion plant located in the study area, with a corresponding increase in the market area for biomass harvested within the region.

Each of the alternative futures is summarized in terms of the following impact factors: land utilization, land values, farm incomes, farm expenditures, and farm employment and payroll. These factors were selected because it was felt that essentially all of the significant direct economic impacts to a region's agricultural sector could be summarized under one of these impact categories.

1. Construction of a Small (500 ton/day) Biomass Conversion Plant:

Location of a 500 ton/day conversion plant near the center of the study region would have quite localized impacts on the agricultural economy of the 11-county area. For example, it has been estimated that, if the plant were located in Thurston County, Nebraska,* approximately 157,000 acres in the region would meet least cost criteria for biomass harvest and therefore would probably constitute the primary market area. Over 60% of this acreage would be within the county where the plant was located. For example, in Thurston County, about 97,000 acres of land now in corn, wheat, oats, and hay production, primarily corn, would provide forage and crop residue which would meet least cost criteria established for the conversion plant feedstock. In addition, about

* The linear programming model assumed the northeast corner of Thurston County, Nebraska as the approximate center of the region for the computer analysis. However, the presence of two Indian reservations in Thurston County (The Winnebago and the Omaha Indian Reservations) would complicate the site selection process considerably if that location were actually under consideration.

10,000 acres in both Cedar County and Burt County, Nebraska (cropland presently in hay and wheat) would be cost competitive with biomass harvest in Thurston County. Residue from the additional 40,000 acres of the total 157,000 acres needed to maintain the conversion plant at 500 ton/day production would be distributed among the other eight counties, on cropland now in wheat or hay.

Assuming an average size of farms in Thurston County of about 329 acres (USDA, 1974), of which approximately 300 acres are in harvested cropland, over 300 farms in Thurston County and an additional 200 farms in nearby counties would meet least cost criteria for biomass harvesting. Therefore, of the approximately 11,500 farms in the region which now raise crops, slightly over 4% of the farms could meet least cost criteria for biomass harvest and these farmers could have a market for their crop residue of corn, hay, and/or wheat. Under the assumption of the linear programming model, essentially all of the residue left on these 500 farms after harvest of corn, wheat or oats would have a cost-effective market at the plant. There would be no significant change in current cropping patterns or land utilization and most of the market for residue material would be rapidly absorbed by Thurston County.

Where farmers would have an incentive to harvest their crop residue, due to locational advantages near the conversion plant and/or the type of crops and residue available, a pattern of events might be fairly predictable. Utilizing the selected categories of impact factors--land utilization, land value, farm income, farm expenditures, and farm employment, and payroll--Table 62 lists expected impacts in the region and on local farms from siting of a 500 ton/day biomass conversion plant.

2. Construction of a 1,000 ton/day Biomass Conversion Plant: Construction of a 1,000 ton/day conversion plant near the center of the study region would provide market opportunities for crops on an estimated 292,000 acres meeting the criteria of minimizing total cost: 111,000 acres in Thurston County, 67,000 acres in Dakota County, 56,000 acres in Burt County, and 10,000 acres or less in the remaining eight counties in the region. Residue from corn and oats would continue to be the primary biomass crops, supplying over 90% of the residue, with wheat providing a secondary source, and a small portion also coming from cropland planted to barley. This would mean that in Thurston and Dakota counties, for example, essentially all of the residue from cropland currently in corn, wheat, oats and barley would be cost competitive for sale to the conversion plant. Similarly, in Burt County, all of the land now planted to wheat, barley, and hay and about one-third of the land in corn would meet minimum cost criteria for residue harvesting.

TABLE 62

PRIMARY NEAR-TERM ECONOMIC IMPACTS TO THE FARMS IN AN AGRICULTURAL
REGION WITH LOCATION OF A 500 T/DAY BIOMASS CONVERSION PLANT

Land Utilization

1. High and medium grade croplands with currently high yields will continue as presently utilized throughout the region.
2. Some low grade cropland in the primary market area may be utilized for corn, wheat, or hay if the combined sale of the crop and residue provides an economic incentive for the change.
3. There will be a conversion of some previously undeveloped land at the site of the conversion plant.
4. Depending on the size of the nearby local community, the influx of 15 to 23 employees to run the conversion plant could stimulate new residential development.

Land Value

1. In the primary market area, per acre value of cropland will rise, reflecting the supplemental crop residue market.
2. Residential properties in the town most accessible to employees of the conversion plant may rise in value as housing demand increases.

Farm Income

1. Wherever crop residues are harvested and sold, land owners will realize increased net farm income.
2. Income earned on-farm may rise relative to off-farm income on farms in the primary market area as farmers increase time and investment in residue harvest.

Farm Expenditure

In the primary market area, the decision to harvest crop residues will:

TABLE 62 (Concluded)

1. Increase per acre production costs due to different management and harvesting operations being applied.
2. Increase harvesting costs generally, including labor, fuel, specialized equipment, and machine repair. Where whole crops are involved, all costs will increase.
3. Stimulate increased expenditures for fertilizer.

Employment and Payroll

1. Farm owners in the primary market area may hire additional seasonal farm workers for residue harvest. Generally, though, the biomass harvest will probably involve longer use of current hired farm workers, with accompanying payroll increases or, more frequently, custom harvesting.
2. New sources of regional employment and income will likely include custom harvesting, sales and repair of harvesting equipment and transportation.
3. Depending on the process utilized, the conversion plant will require an estimated 15 to 23 employees. It is expected that most of these workers will receive on-the-job training and will be hired from the unemployed or underemployed sectors of the region's labor force.

Table 63 summarizes the near-term potential impacts to the region's farming community with a 1,000 ton/day conversion plant.

3. Construction of a 3,000 ton/day Biomass Conversion Plant:

It was estimated that with 3,000 tons/day conversion plant the following six counties would have significant croplands meeting least cost criteria: Woodbury County, 258,000 acres; Burt County, 146,000 acres; Cuming County, 123,000 acres; Thurston County, 111,000 acres; Dakota County, 68,000 acres; and Wayne County, 35,000 acres. These six counties would comprise 95% of the total 781,000 acres meeting least cost criteria. Table 64 summarizes the impacts on the 5 impact categories from a 3,000 ton/day conversion plant.

TABLE 63

PRIMARY NEAR-TERM ECONOMIC IMPACTS TO FARMS IN AN AGRICULTURAL REGION
WITH LOCATION OF A 1000 T/DAY BIOMASS CONVERSION PLANT

Land Utilization

1. High and medium grade croplands will continue as presently utilized, with the added harvest of crop residues in the primary market area.
2. Some low grade cropland in the primary market area may shift to crops such as wheat, barley, and hay if these crops offer a higher income potential when residue harvest is considered.
3. Some cropland in cover crops which currently is not harvested or pastured, cropland in summer fallow, and idle cropland in the primary market counties may be converted to harvested crops of grains or hay.
4. Thurston and Dakota Counties will definitely reflect the proximity of the conversion plant with over 1/2 of the farms in both counties harvesting crop residues.
5. There will be an irreversible loss of some previously undeveloped land at the site of the conversion plant.
6. Depending on the size of the nearby local community, the influx of 15 to 23 employees to run the conversion plant could stimulate additional residential development.

Land Value

1. On harvested croplands in the primary market area (Thurston, Dakota, and Burt Counties) land values are expected to rise, reflecting added per acre value of residue harvested.^{1/}
2. The rise in land values will be reflected as an increase in total assets, or net worth of the farms. Thus, net worth for those farms in the primary market area will increase (even if the farmer does not opt to harvest the biomass.)

^{1/} Since cropland values are determined by crop prices, soil productivity, soil classification type, and the proximity of urban areas, the added market opportunity for crop residue will, in effect, add value to the crop price factor, thereby stimulating land values.

TABLE 63 (Concluded)

3. Values of residential land near the conversion plant will increase.
4. The value of low grade cropland may rise more (relative to middle and high grade land) due to residue market opportunities.
5. The value of woodlands on lands nearest the conversion plant may increase.

Farm Income

1. Farmers in the primary market area who harvest biomass will realize increased net farm income and therefore an increased liquidity position relative to farmers in the rest of the region.
2. Farmers who harvest biomass and also make an investment in specialized equipment to do the harvesting for other farmers, will likely realize the greatest relative income gain and improved liquidity position (custom harvesting may decline in the long-run as more farmers purchase their own equipment.)

Farm Expenditures

Expenditures attributed to farmers affected by the 500 T/day plant (see Table 61) will affect a larger number of farms.

Employment and Payroll

1. Specialized harvesting and hauling industries will expand to a regional market.
2. The conversion plant will require approximately the same number of employees for a 1000 T/day operation as for a 500 T/day operation.
3. Some of the region's seasonal labor force will likely be hired for a longer season due to biomass harvest operations.

TABLE 64

PRIMARY NEAR-TERM ECONOMIC IMPACTS TO FARMS IN AN AGRICULTURAL REGION
WITH LOCATION OF A 3000 T/DAY BIOMASS CONVERSION PLANT

Land Utilization

1. High and medium grade croplands will continue as presently utilized in the 6-county primary market area.
2. Most low grade cropland will shift to crops such as corn or wheat which offer a higher income potential due to the market for biomass. Nearly all cropland in the primary market area will be harvested.
3. Some conversion of scrub woodlands or wetlands to harvested cropland will likely be attempted by farmers in the primary market area.
4. Idle land, woodlands, or wetlands which are converted to harvested cropland will have lose recreational utility to the regional population.
5. On a regional basis, there will be a measurable amount of land used for storage of on-farm residue.
6. Large-scale operations to rent marginal land for biomass harvest may be organized.
7. Woodbury, Burt, Cuming, Thurston, and Dakota Counties will reflect the greatest impact from the plant's proximity, with over 2000 farms involved in biomass harvesting.
8. There will be an irreversible loss of some previously undeveloped land at the site of the conversion plant.
9. Depending on the size of the nearby local community, an influx 26-40 employees to run the conversion plant may stimulate new residential development.

Land Value

1. In the primary market area, per acre value of cropland will rise, reflecting the potential for added per acre value of residue harvested.
2. Increased land values will be reflected as an increase in total assets, or net worth, of farms in the primary market area.

TABLE 64 (Concluded)

3. Values of residential land near the conversion plant will increase.

Farm Income

1. More intensive land utilization due to residue harvesting may lower crop prices on a regional basis, thereby reducing incomes of those farmers who are in the region but beyond the primary market area for residue harvesting.

2. Farmers in the primary market area who harvest biomass will realize increased net farm income and therefore an increased liquidity position relative to farmers in the rest of the region.

3. Farmers who harvest biomass and also make an investment in specialized equipment to do the harvesting for other farmers, will likely realize the greatest relative income gain and improved liquidity position. (Custom harvesting may decline in the long-run as more farmers purchase their own equipment.)

Farm Expenditures

Expenditures attributed to farmers affected by the 500T/day plant will affect a larger number of farms in the region.

Employment and Payroll

1. Specialized harvesting and hauling industries will expand to a regional market.

2. The conversion plant will require 26 to 40 employees. It is expected that most of these persons will come from within the region's labor force.

3. Much of the region's seasonal hired farm labor will be employed for a longer season in order to assist in the biomass harvest operations.

VI. INSTITUTIONAL ANALYSIS

The regional economic analysis assesses the impact of a biomass conversion plant on one of the study areas. The impact areas under study include land utilization, land values, farm income, farm expenditure, and employment and payroll. These impacts can be aggregated to determine overall program effects.

The objective of the institutional analysis is to determine the feasibility of using grains and residues for ethanol from a political-economic perspective. The factors to be included in this section are an overview of how an ethanol from grains and residues program could be funded, and a review of the overall impacts on other sectors of the agricultural economy.

A. Use of Current USDA Programs for Subsidization

It may be possible to aid the commercialization of a gasohol program by using current USDA land diversion payment programs to subsidize ethanol production from grains and crop residues.

The U.S. Department of Agriculture is currently authorized to utilize one of two programs or both concurrently, to support food and feed prices by withholding land from production. In the land set-aside program, a farmer may idle a specified percentage of land devoted to a program crop without direct subsidy for the acreage set aside. The incentive to participate in this program is eligibility for other program benefits (commodity loans, deficiency payments, disaster payments, and grain reserve storage payments) which are not available to nonparticipants.

A land diversion program may be authorized with or without a set-aside and provides the producer with a direct payment or subsidy based on historical yields and actual production of the crop in the designated crop year.

From 1961 through 1973, the quantity of land withheld from production as a result of USDA programs varied from 20 million acres to 65 million acres. In all of these years but 1973, at least 37 million acres were withheld from production (Table 65).

Under provision of the Agricultural and Consumer Protection Act of 1974, which applied to the 1974 through 1977 crops, virtually no land was withheld from production under federal programs. The Agricultural Act of 1977 again authorized a program of production restraint and an estimated 4.6 million acres were set aside from total feed grain production and an additional 3.1 million acres were diverted for payment. An estimated 8.4 million acres were set aside from wheat production, while

TABLE 65

CROPLAND WITHHELD FROM FEED GRAIN, WHEAT, AND OTHER CROPS (1961-73)
(Data in Million Acres)

<u>Year</u>	<u>Corn</u>	<u>Sorghum</u>	<u>Barley</u>	<u>Total Feed Grains</u>	<u>Wheat</u>	<u>Other^{a/}</u>	<u>Total</u>
1961	19.1	6.1	--	25.2	--	28.5	53.7
1962	20.3	5.5	2.4	28.2	10.7	25.8	64.7
1963	17.2	4.6	2.7	24.5	7.2	24.4	56.1
1964	22.2	6.5	3.7	32.4	5.1	17.6	55.1
1965	24.0	7.0	3.7	34.8 ^{b/}	7.2	15.4	57.4
1966	23.7	7.3	3.7	34.7	8.3	20.3	63.3
1967	16.2	4.1	--	20.3	--	20.4	40.7
1968	25.4	7.0	--	32.4	--	17.0	49.4
1969	27.2	7.5	4.4	39.1	11.1	7.8	58.0
1970	26.1	7.4	3.9	37.4	15.7	4.0	57.1
1971	14.1	4.1	--	18.2	13.5	5.9	37.6
1972	24.4	7.3	4.9	36.6	20.1	5.4	62.1
1973	6.0	2.0	1.4	9.4	7.4	2.8	19.6
1974	--	--	--	--	--	2.4	2.4
1975	--	--	--	--	--	2.4	2.4

Source: Agricultural Statistics, USDA.

a/ Includes acres withheld from cotton, for cropland conversion or cropland adjustment, as well as the older Conservation Reserve.

b/ Includes a small amount withheld from oats.

approximately 1.4 million acres were allowed to be grazed from additional set aside land for payment.

Land diversion payments can be substantial. Such payments for the total crop of 1978 feed grains (corn, grain sorghum and barley) are estimated to total \$503 million. If the 1978 program provisions are continued unchanged in 1979 (10% set aside and 10% diversion) projected diversion payments would total \$594 million.

The prices brought by grains in the current food and feed market effectively prohibit its use as a feedstock for ethanol sold as a fuel. A Battelle report (Battelle Columbus Laboratories, 1978) found that with grain feedstocks cost at \$1.25/bushel, \$2.50/bushel and \$3.00/bushel, the corresponding total cost of ethanol would be \$0.95/gal., \$1.43/gal. and \$1.62/gal., including credits for ester aldehyde and distillers dried grain. In the first part of November, Chicago prices for the major feedstocks--corn, wheat and sorghum were averaging \$2.30, \$3.34 and \$2.52/bushel, respectively. These grain prices are supported, in part, through USDA programs of production restrictions and price supports. Paradoxically, farmers receive subsidies to maintain grain prices, while an ethanol program from grain and residues would require subsidization to be competitive in the current fuel market.

However, land diversion payments could be utilized to reduce feedstock costs. For example, in the 1978 crop year the USDA announced a 10% set-aside with an additional 10% paid diversion. If a producer complied with the set-aside requirement and also decreased his feed grains acreage by an additional 10%, he received payment of 20¢/bushel for corn, or 12¢/bushel for sorghum or barley, on the normal (historical) production from the remaining 80% of his acres planted for harvest. Considering the previous year's average yield per acre was 90.8, 56.0 and 44.0 bushels per acre, respectively, the diversion payment resulted in average government payments per diverted acre of:

Corn	\$145
Sorghum	52
Barley	42
Weighted Average	\$130

Assuming that diverted land is planted in corn, a yield of 2.5 gal. of ethanol per bushel would give 226 gal./acre. Thus, the subsidy for diverted acreage translates into a theoretically available 58¢/gal. subsidization for ethanol produced from diverted land, without requiring additional subsidy expenditures. The estimated 5 million acres of diverted land in 1978 could thus yield 1.1 billion gal. of

ethanol, with subsidy of 48¢/gal. Using both set-aside and diverted land in the 1978 program could yield 40 billion gal. of ethanol, but would reduce the available subsidy to 16¢/gal.

This use of diversion payments would require enabling legislation. One problem which would be encountered in seeking legislative approval is the institutionalization of a subsidy which under previous USDA programs has been intermittent. A second and potentially more significant problem is the possibility that specially constructed alcohol plants will at some stage face a loss of feedstocks due to food competition for crop or land. However, if the plants could utilize both grain and grain residues feedstocks shortages could be alleviated.

B. Impacts on the Agricultural Sector

One of the major by-products of ethanol production from fermentation and distillation is distillers dried grain. Distillers grain from corn, sorghum and wheat, has a high protein content and is easily substituted for other animal feeds, particularly soybean meal. During the first part of November, distillers grain has been selling for around \$108/ton, while soybean meal during the same time has sold for \$169/ton. The price of distillers grain is expected to be bid up if it became more readily available, for all output is currently forward contracted and sold close to the source of supply. Even with substantial price increases, distillers grain would still be favored over soybean meal. This could result in depressed prices in the soybean complex. A disruption in the soybean complex would alter the price relationships in markets for which soybean meal or oil is an input. This could impact fed cattle operations, and industries utilizing fats and oils such as soap producers, fatty acid producers, and the poultry feed industry.

VII. ENVIRONMENTAL IMPACTS

The potential environmental impacts of energy from biomass include several which are usual with any energy system involving carbon-based energy sources, plus impacts which are specific to biomass production. In the former category are included the possible impacts from combusting biomass or from other processes for converting input biomass into output energy forms. These include generation of air pollutants exemplified by particulate matter; sulfur oxides; and nitrogen oxides; solid residues (ashes, sludges, and other by-products); water pollutants; and thermal pollution.

The potential impacts which are relatively unique to biomass are related primarily to biomass production, transportation, and storage. These include fugitive air emissions from the grass or grain production operation, fugitive air emission from biomass storage, transportation, and preprocessing operations; and the nonpoint emissions to surface or groundwaters which may accompany biomass growth with special emphasis being given to the impacts which may accompany implementation of options which require greater use of land, more complete removal (harvest) of biomass, or greater overall use of fertilizers or pest control agents. The possible impacts may be considerably broader than a rather narrow consideration of the probable impact on any one media such as surface water, and accordingly extend to possible significant modifications of the ecological system or balance within a region such as might accompany evolvement from present 50% utilization of a region's land resource for grain and hay production, to 75 to 80% utilization of the same resource for combined grain and biomass production. The more extensive land use might thus destroy or reduce habitats for wildlife including endangered species and in the broader sense seriously disrupt the basic balance in a region's ecological systems.

Agricultural production as it presently is structured faces the continuing problem of protecting or conserving the productivity of the land--a problem which is only partially resolved by current efforts to implement conservation programs and limit uses of types of land to crops or cultural practices which conserve the resource. The problem is compounded by the trend toward larger, more cost-effective equipment which is less compatible with farming on terraces than small equipment. In principle, this problem will be accentuated by biomass-for-energy since the biomass made available for energy will come from some combination of crop residue utilization, shifts in crop mixes, and more extensive land use. In practice, however, biomass grown for energy use may involve greater use of perennial grasses with an accompanying opportunity to provide built-in conservation practices not possible with annual crops; and the overall production system might be implemented with conservation practices implicit in the management system.

Not to be discounted in an energy plus food oriented agricultural production system are the dangers of introducing difficult-to-control plants which may become pests, of introducing new diseases, or of aggravating existing diseases and pests. For these reasons, any significant modification to the agricultural production system of a region or area should be carefully reviewed to determine in advance whether potential problems are severe enough to warrant either a decision not to implement, or a research-oriented approach which permits development of mitigating measures.

One factor which is relatively unique to biomass-for-energy is the bulk or volume factor. The absolute density of plant biomass is less than that of water, and practically achievable bulk densities are 15 to 25% of the densities of water. Further, reasonable economy in harvesting and handling forage-type biomass is predicated on natural drying and minimal protection from moisture after harvest. The low bulk density translates to a large storage area and volume. With unprotected storage, bales or residue or hay cannot be stored in large, consolidated stacks, and drainage in the storage area should be excellent to minimize wetting bales exposed to the ground. Inadequate protection from moisture will result in loss of biomass from decomposition and may also result in accelerated loss through combustion processes akin to the similar problem in coal piles. Further, fire protection will be a problem of no little magnitude. A considerable part of the environmental and safety impact of plant biomass, therefore, revolves around the storage of the conversion-site inventories of the biomass. In its broadest terms, this problem, includes the possibility that large inventories of biomass may generate environmentally significant quantities of organic emissions which accompany degradation under storage.

With this background, potential environmental impacts of the growth and use of plant biomass for energy include the following:

A. Production-Related Impacts

1. Impacts on soils:

a. Increased wind and water erosion: Causes--removal of biomass cover; cultivation of more erodible soils.

b. Decreased productivity: Causes--erosion, organic matter depletion, nutrient removal without replacement.

2. Impacts on water quality:

a. Surface water quality: From increased sediments and sediment borne pollutants; greater use of fertilizers and pesticides.

b. Groundwater quality: From increased contamination with nitrate due to increased fertilization, or from alteration of hydrology.

3. Impacts on air quality: From fugitive emissions generated in cultivation and harvesting; possible increases in wind erosion.

4. Impacts on fish and wildlife: From destruction of habitats.

5. Secondary impacts: From modification of ecological systems.

6. Impacts on water quantity: Extension of irrigation to energy crops will intrude on water supplies with the magnitude of the impact depending on the relative availability of irrigation water in a region.

B. Transportation - Related Impacts

Primarily fugitive dusts from road traffic.

C. Storage Related Impacts

1. Uncontained run-off from storage areas containing suspended organic matter and substances leached from stored biomass.

2. Fugitive dusts and organic chaff from handling biomass.

3. Airborne organic matter from slow degradation of stored biomass.

4. Potential air emissions from accelerated decomposition of biomass.

5. Potential air emissions from fire, which constitutes a greater danger than with coal.

D. Potential Impacts from Preprocessing Biomass

Biomass as supplied from the field will usually require some type of preprocessing to convert it to a form suitable for charging to conversion processes. Preprocessing operations can be the source of a considerable quantity of dust and chaff. Without proper controls, this can be a fire hazard, a source of direct emissions to the air, and a source of indirect emissions to surface waters.

E. Potential Impacts from Conversion Processes

These will vary from process to process.

1. Direct combustion will yield particulate and gaseous emissions determined by the design of the burner and associated controls. In general terms, biomass will pose much less of a problem with respect to sulfur oxide emissions; will be similar to other fuels with respect to nitrogen oxide emissions; and will generate ashes containing metals in proportions typical of supplied biomass. Disposal of ash on land, if carried out on a return-to-the-soil basis, should pose no significant environmental hazard; if disposal is effected in a manner customary to the power industry, problems typical of concentrated disposal (i.e., leaching of metals) will be encountered and must be dealt with by environmentally-acceptable procedures.

2. Thermochemical processes will face environmental problems generally similar to analogous processes in which coal is the feedstock. These processes feature a more rigorous containment of possible air pollutants than does direct combustion and in this sense should pose less of a threat to air quality.

3. The biological or biochemical processes have in common the feature that substantial quantities of by-product water-carried sludges are generated along with water soluble matter which would be a very substantial environmental problem if it is not further utilized or is not properly treated or disposed. Fermentation sludges are valued as livestock feed, and this use is assumed for these by-products. Sludges from anaerobic digestion are potential livestock feed, as well as candidates for direct return to the land on which the biomass was produced. An alternate use consists of drying and recovery of residual energy values via combustion. The options for managing the by-products or wastes, in order to be environmentally acceptable, must include provisions for treating waste liquors; complete recycle (zero discharge) would be preferred. Even a small biological conversion plant (500 tons/day or less) will generate hundreds of tons per day on a dry weight basis. If sludges from anaerobic digestion are returned to the land, the method will be acceptable only to the extent that the procedure for land application is conducted according to good practice. If the sludge is not de-watered, the mass for disposal will exceed the mass of the biomass from which it was derived. De-watering of the sludge will create a liquor laden with polluting substances and this must be further treated and/or recycled back into the digestion system. These comments are made to accent the fact that disposal on land is inherently very simple in principle, but presents significant considerations with regard to how

the sludge is treated, transported and ultimately disposed on the land. A 500 ton/day conversion plant will yield by-product sludges in quantities comparable to quantities of municipal sludge generated by a population of about 1 million people, and will present much the same problems of logistics and cost encountered in municipal sludge disposal on land.

The environmental impacts associated with the conversion plant are thus generally similar to those of analogous energy plants, but differ in the extent or magnitude of specific impacts. Again speaking generally, these impacts are susceptible to control, so that adverse impacts should be kept within the boundaries or standards specified for air quality, water quality, and land quality.

Those impacts associated with biomass production are basically the same as the impacts of current agricultural production. Some of the impacts can be expected to increase in proportion to additional acreage placed in production. If the added acreage is not developed in accordance with good management practice, the impacts can be more severe than expected from a simple addition of acres. This statement applies particularly to erosion. If on the other hand the modified production system is structured around sound management practices, the opportunity exists to actually decrease erosion in a given region. The environmental consequence of the action are accordingly subject to control--at least as far as erosion and erosion-related pollutants are concerned.

A further consideration is the type of biomass grown. On the one hand, shifts toward annual cultivated crops will increase the amount of land subject to erosion; such a shift, particularly if it involves marginal land, should be implemented only with adherence to conservation practices. If the biomass, on the other hand, consists of perennial grasses, the potential for erosion is substantially less, and well managed perennials may be even less of a source of erosion than poorly managed pasture.

In summary, the erosion impact could be very severe if biomass is grown on expanded acreages without careful consideration of land use limitations, management practices, and types of crop. If these factors are taken into consideration and acted upon, it is possible to actually reduce erosion below present levels. A particularly attractive option in this regard is the growth of perennial grasses.

The modified crop production systems developed for the Nebraska/Iowa region exemplify a system which offers the opportunity to both enhance the capability of the region to increase production of biomass available for energy, and to effect an overall improvement in soil and land conservation--and concurrently to lessen impacts of sediments and sediment-born pollutants on surface waters. The production systems range from a grain-dominated scenario to a grass-hay dominated scenario. The possible

adverse impacts of these modified production systems would appear to be the following:

1. The land area dedicated to production of harvested crops has been increased from about 2.9 million acres to 3.9 million acres. Whether the added acreage is devoted to cultivated crops or to managed perennial hay crops, such things as habitats for wildlife will be significantly modified and, consequently, reduction of numbers of some species populations. Without conducting a detailed study of the area, it is not possible to predict the consequences of the action in any detail. One can, however, predict that wildlife will be significantly impacted, and that a new distribution of species can be expected. The secondary impacts on the basic ecology of the region will similarly be difficult to predict.

2. The overall more intensive management of crops in the region will require heavier use of fertilizer. Some of the management practices involve terracing with attendant changes in hydrology (run-off to streams, percolation into soils and groundwaters). One production system has a higher proportion of grass than at present, which will also affect hydrology. It is possible that certain of the suggested actions will increase transmission of pollutants, particularly nitrate, into groundwaters.

3. One can readily propose quite substantial changes in the distribution of crops among land capability classes. It is considerably more difficult to assess in detail the effects these changes will have on individual farms and on the distribution of crops and livestock within the region. It is probable, for example, that livestock populations would have to be redistributed to be compatible with the modified production systems, and that a lesser fraction of the roughage fed to cattle would be supplied by grazing. The consequent shift to confinement type feeding together with re-distribution of livestock would compound the problem of livestock waste management.

In overall terms, therefore, the energy oriented production systems developed for the Nebraska/Iowa region offer the attractive feature of significantly lessening one environmental problem--erosion and sediment borne pollutants. The benefit in this respect may be partially offset by adverse impacts. Of these, the most difficult to quantify or put into perspective is the impact or impacts associated with nearly complete utilization of the land resource under uniformly good farm management practices. Such an action will cause a significant, but difficult to quantify and evaluate, change in the existing terrestrial ecological system; will exert an effect on hydrologic parameters which may translate to an adverse impact on water quality; and will burden the region or area with added inputs of fertilizers and pest control agents which may in turn have adverse impacts. All of these potential impacts

are of the type that would be of little consequence with limited or isolated action, but assume significant importance given the proposed magnitude of the changes.

The environmental implications of proposed modifications in the Georgia region are similar to those in the Nebraska/Iowa region. The modifications are in the direction of utilizing the land for growth of biomass crops which limit erosion, but at the same time require more extensive land use and improved management of crops. The Georgia region less effectively utilizes plant nutrients, and the greater use of fertilizers portends greater movement of nutrients into surface and groundwaters. As with the Nebraska/Iowa region, changes in the ecological balance would be expected.

The above discussion leads to the following general conclusion.

a. Utilization of grasses and grains for energy purposes, particularly with an expanded land base, can have serious adverse environmental and land resource consequences if heed is not given to the approach implemented in the production areas.

b. Some of the possible adverse impacts can be mitigated if appropriate action for conservation of natural resources is used as an integral part of the land use plan, and the opportunity exists to improve upon the present situation.

c. If an increasing dedication of the agricultural resource occurs in response to energy needs, certain changes in terrestrial ecological systems will occur. These changes or impacts would seem to be unavoidable, although the extent and significance of an impact can be controlled with good planning. The possible impacts range from peril to endangered species, though degradation of recreational values from wildlife, to secondary impacts from disruption of ecological balances.

d. Extensive changes in land cover, in disturbance of soils, increases in fertilizer and pesticide use, and similar factors implicit in substantial biomass-for-energy production will be the source of fairly long-term potential effects on impact areas such as groundwater quality and hydrology. The significance of such impacts is not readily predicted and is properly the subject of additional study.

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APPENDIX A

MINIMUM COST BIOMASS, RESIDUES AND HAY

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
ARKANSAS REGION

TABLE A-1

TOTAL BIOMASS

Crop area	2,862,400
Crop area used	107,859
Percent area used	3.8
Available biomass (OD tons)	1,196,323
Biomass used (OD tons)	165,000
Percent biomass used	13.8
Harvest costs ^{a/}	15.65
Nutr replacement cost ^{a/}	7.80
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	15.63
Transport cost ^{a/}	3.39
Total cost ^{a/}	42.61

a/ Average cost per oven dry ton

TABLE A-2

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>RIC</u>
Total acres	166,700	497,500
Acres used	47,600	60,259
Available biomass (OD tons)	184,337	1,011,986
Biomass used (OD tons)	51,038	113,962
Percent crops used	30.9	69.1
Biomass (OD tons/acre)	1.10	2.03
Cost ^{a/} (\$/OD ton)	39.09	39.28

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
ARKANSAS REGION

TABLE A-3

TOTAL BIOMASS

Crop area	2,862,400
Crop area used	194,288
Percent area used	6.8
Available biomass (OD tons)	1,196,323
Biomass used (OD tons)	330,000
Percent biomass used	27.6
Harvest costs ^{a/}	15.65
Nutr replacement cost ^{a/}	7.81
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	15.64
Transport cost ^{a/}	3.76
Total cost ^{a/}	43.01

a/ Average cost per oven dry ton

TABLE A-4

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>RIC</u>
Total acres	166,700	497,500
Acres used	54,300	139,988
Available biomass (OD tons)	184,337	1,011,986
Biomass used (OD tons)	56,969	273,031
Percent crops used	17.3	82.7
Biomass (OD tons/acre)	1.11	2.03
Cost ^{a/} (\$/OD ton)	39.09	39.28

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD. TONS/DAY
ARKANSAS REGION

TABLE A-5

TOTAL BIOMASS

Crop area	2,862,400
Crop area used	555,790
Percent area used	19.4
Available biomass (OD tons)	1,196,323
Biomass used (OD tons)	990,000
Percent biomass used	82.8
Harvest costs ^{a/}	15.65
Nutr replacement cost ^{a/}	7.81
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	15.64
Transport cost ^{a/}	5.83
Total cost ^{a/}	45.08

a/ Average cost per oven dry ton

TABLE A-6

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>RIC</u>
Total acres	166,700	497,500
Acres used	150,000	405,790
Available Biomass (OD tons)	184,337	1,011,986
Biomass used (OD tons)	163,595	826,405
Percent crops used	16.5	83.5
Biomass (OD tons/acre)	1.11	2.03
Cost ^{a/} (\$/OD ton)	39.09	39.28

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
CALIFORNIA REGION

TABLE A-7

TOTAL BIOMASS

Crop area	1,309,480
Crop area used	49,819
Percent area used	3.8
Available biomass (OD tons)	4,245,881
Biomass used (OD tons)	165,000
Percent biomass used	3.9
Harvest costs ^{a/}	16.73
Nutr replacement cost ^{a/}	7.28
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	16.01
Transport cost ^{a/}	2.84
Total cost ^{a/}	43.00

a/ Average cost per oven dry ton

TABLE A-8

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>
Total acres	312,400
Acres used	49,819
Available biomass (OD tons)	812,823
Biomass used (OD tons)	165,000
Percent crops used	100
Biomass (OD tons/acre)	2.60
Cost ^{a/} (\$/OD ton)	40.16

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
CALIFORNIA REGION

TABLE A-9

TOTAL BIOMASS

Crop area	1,309,480
Crop area used	106,179
Percent area used	8.1
Available biomass (OD tons)	4,245,881
Biomass used (OD tons)	330,000
Percent biomass used	7.8
Harvest costs ^{a/}	16.73
Nutr replacement cost ^{a/}	7.40
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	16.09
Transport cost ^{a/}	2.84
Total cost ^{a/}	43.20

^{a/} Average cost per oven dry ton

TABLE A-10

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>BAR</u>	<u>SGG</u>	<u>RIC</u>
Total acres	312,400	533,500	44,200	32,000
Acres used	75,000	22,179	8,000	1,000
Available biomass (OD tons)	812,823	1,439,289	33,431	72,612
Biomass used (OD tons)	248,400	73,634	5,735	2,231
Percent crops used	75.3	22.3	1.7	0.7
Biomass (OD tons/acre)	2.60	2.70	0.76	2.27
Cost ^{a/} (\$/OD ton)	40.16	41.04	40.27	40.29

^{a/} Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD TONS/DAY
CALIFORNIA REGION

TABLE A-11

TOTAL BIOMASS

Crop area	1,309,480
Crop area used	311,651
Percent area used	23.8
Available biomass (OD tons)	4,245,881
Biomass used (OD tons)	990,000
Percent biomass used	23.3
Harvest costs ^{a/}	16.73
Nutr replacement cost	7.52
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	16.17
Transport cost ^{a/}	3.60
Total cost ^{a/}	44.17

^{a/} Average cost per oven dry ton

TABLE A-12

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>BAR</u>	<u>SGG</u>	<u>RIC</u>
Total acres	312,400	533,500	44,200	32,000
Acres used	164,751	137,900	8,000	1,000
Available biomass (OD tons)	812,823	1,439,289	33,431	72,612
Biomass used (OD tons)	524,206	457,828	5,735	2,231
Percent crops used	53.0	46.2	0.6	0.2
Biomass (OD tons/acre)	2.60	2.70	0.76	2.27
Cost ^{a/} (\$/OD ton)	40.16	41.04	40.27	40.29

^{a/} Transport costs not included

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
GEORGIA REGION

TABLE A-13

TOTAL BIOMASS

Crop area	1,169,623
Crop area used	112,884
Percent area used	9.7
Available biomass (OD tons)	827,308
Biomass used (OD tons)	165,000
Percent biomass used	19.9
Harvest costs ^{a/}	15.65
Nutr replacement cost ^{a/}	5.34
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.00
Transport cost ^{a/}	3.89
Total cost ^{a/}	39.02

a/ Average cost per oven dry ton

TABLE A-14

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>PEA</u>
Total acres	259,735
Acres used	112,884
Available biomass (OD tons)	382,277
Biomass used (OD tons)	165,000
Percent crops used	100
Biomass (OD tons/acre)	1.47
Cost ^{a/} (\$/OD ton)	35.13

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
GEORGIA REGION

TABLE A-15

TOTAL BIOMASS

Crop area	1,169,623
Crop area used	223,776
Percent area used	19.1
Available biomass (OD tons)	827,308
Biomass used (OD tons)	330,000
Percent biomass used	39.9
Harvest costs ^{a/}	15.65
Nutr replacement cost ^{a/}	5.35
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.01
Transport cost ^{a/}	5.28
Total cost ^{a/}	40.43

a/ Average cost per oven dry ton

TABLE A-16

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>FEA</u>
Total acres	19,300	259,735
Acres used	1,590	222,186
Available biomass (OD tons)	17,987	382,277
Biomass used (OD tons)	1,991	328,009
Percent crops used	0.6	99.4
Biomass (OD tons/acre)	1.08	1.47
Cost ^{a/} (\$/OD ton)	39.60	35.13

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
ILLINOIS REGION

TABLE A-17

TOTAL BIOMASS

Crop area	3,016,600
Crop area used	89,922
Percent area used	3.0
Available biomass (OD tons)	5,499,025
Biomass used (OD tons)	165,000
Percent biomass used	3.0
Harvest costs ^{a/}	13.38
Nutr replacement cost	7.25
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	13.75
Transport cost ^{a/}	4.45
Total cost ^{a/}	38.97

a/ Average cost per oven dry ton

TABLE A-18

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>	<u>RYE</u>
Total acres	1,672,100	100,100	47,100	5,600
Acres used	8,223	78,200	3,300	200
Available biomass (OD tons)	5,014,499	176,251	94,213	194
Biomass used (OD tons)	24,372	133,604	6,871	154
Percent crops used	14.8	81.0	4.2	0.1
Biomass (OD tons/acre)	3.00	1.76	2.00	0.78
Cost ^{a/} (\$/OD ton)	38.03	33.72	37.73	32.54

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
ILLINOIS REGION

TABLE A-19

TOTAL BIOMASS

Crop area	3,016,600
Crop area used	145,590
Percent area used	4.8
Available biomass (OD tons)	5,499,025
Biomass used (OD tons)	165,000
Percent biomass used	6.0
Harvest costs ^{a/}	13.38
Nutr replacement cost ^{a/}	8.30
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.45
Transport cost ^{a/}	3.41
Total cost ^{a/}	39.68

a/ Average cost per oven dry ton

TABLE A-20

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>
Total acres	1,672,100	100,100	47,100
Acres used	63,891	78,200	3,300
Available biomass (OD tons)	5,014,499	176,251	94,213
Biomass used (OD tons)	189,372	133,604	6,871
Percent Crops used	57.4	40.5	2.1
Biomass (OD tons/acre)	3.00	1.76	2.00
Cost ^{a/} (\$/OD ton)	38.03	33.72	37.73

a/ Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD TONS/DAY
ILLINOIS REGION

TABLE A-21

TOTAL BIOMASS

Crop area	3,016,600
Crop area used	364,543
Percent area used	12.1
Available biomass (OD tons)	5,499,025
Biomass used (OD tons)	990,000
Percent biomass used	18.0
Harvest costs ^{a/}	13.38
Nutr replacement cost ^{a/}	8.99
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.92
Transport cost ^{a/}	3.05
Total cost ^{a/}	40.49

^{a/} Average cost per oven dry ton

TABLE A-22

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>
Total acres	1,672,100	100,100	47,100
Acres used	274,593	7,820	11,500
Available biomass (OD tons)	5,014,499	176,251	94,213
Biomass used (OD tons)	832,939	133,604	23,262
Percent crops used	84.1	13.5	2.3
Biomass (OD tons/acre)	3.00	1.76	2.00
Cost ^{a/} (\$/OD ton)	38.03	33.72	37.73

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
KANSAS REGION

TABLE A-23

TOTAL BIOMASS

Crop area	2,613,130
Crop area used	164,335
Percent area used	6.3
Available biomass (OD tons)	2,504,568
Biomass used (OD tons)	165,000
Percent biomass used	6.6
Harvest costs ^{a/}	14.72
Nutr replacement cost ^{a/}	6.32
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.02
Transport cost ^{a/}	2.73
Total cost ^{a/}	37.93

^{a/} Average cost per oven dry ton

TABLE A-24

AVAILABLE BIOMASS USED

<u>CROPS</u>	<u>WHT</u>	<u>BAR</u>	<u>RYE</u>
Total acres	1,702,400	10,100	2,100
Acres used	162,675	630	1,030
Available biomass (OD tons)	1,784,481	16,727	828
Biomass used (OD tons)	162,996	1,211	793
Percent crops used	98.8	0.7	0.5
Biomass (OD tons/acre)	1.05	1.66	0.77
Cost ^{a/} (\$/OD ton)	32.20	36.17	34.11

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
KANSAS REGION

TABLE A-25

TOTAL BIOMASS

Crop Area	2,613,130
Crop area used	326,258
Percent area used	12.5
Available biomass (OD tons)	2,504,568
Biomass used (OD tons)	330,000
Percent biomass used	13.2
Harvest costs ^{a/}	14.72
Nutr replacement cost ^{a/}	6.32
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.02
Transport cost ^{a/}	3.46
Total cost ^{a/}	38.66

^{a/} Average cost per oven dry ton

TABLE A-26

AVAILABLE BIOMASS USED

<u>CROPS</u>	<u>WHT</u>	<u>BAR</u>	<u>RYE</u>
Total acres	1,702,400	10,100	2,100
Acres used	324,598	630	1,030
Available biomass (OD tons)	1,784,481	16,727	828
Biomass used (OD tons)	327,996	1,211	793
Percent crops used	99.4	0.4	0.2
Biomass (OD tons/acre)	1.05	1.66	0.77
Cost ^{a/} (\$/OD ton)	35.20	36.17	34.11

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD TONS/DAY
KANSAS REGION

TABLE A-27

TOTAL BIOMASS

Crop area	2,613,130
Crop area used	964,585
Percent area used	36.9
Available biomass (OD tons)	2,504,568
Biomass used (OD tons)	990,000
Percent biomass used	39.5
Harvest costs ^{a/}	14.72
Nutr replacement cost ^{a/}	6.32
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.02
Transport cost ^{a/}	4.12
Total cost ^{a/}	39.32

^{a/} Average cost per oven dry ton

TABLE A-28

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>BAR</u>	<u>RYE</u>
Total acres	1,702,400	10,100	2,100
Acres used	962,925	630	1,030
Available biomass (OD tons)	1,784,481	16,727	828
Biomass used (OD tons)	987,996	1,211	793
Percent crops used	99.8	0.1	0.1
Biomass (OD tons/acre)	1.05	1.66	0.77
Cost ^{a/} (\$/OD ton)	35.20	36.17	34.11

^{a/} Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
NEBRASKA-IOWA REGION

TABLE A-29

TOTAL BIOMASS

Crop area	2,834,100
Crop area used	131,402
Percent area used	4.6
Available biomass (OD tons)	3,319,881
Biomass used (OD tons)	165,000
Percent biomass used	5.0
Harvest costs ^{a/}	13.38
Nutr replacement cost ^{a/}	9.04
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	14.95
Transport cost ^{a/}	2.37
Total cost ^{a/}	39.89

^{a/} Average cost per oven dry ton

TABLE A-30

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>	<u>BAR</u>	<u>SGG</u>
Total acres	1,445,000	24,180	277,000	5,300	20,870
Acres used	85,992	17,080	25,900	1,900	530
Available biomass (OD tons)	1,621,214	28,329	536,154	8,912	2,003
Biomass used (OD tons)	87,962	19,282	54,131	3,242	383
Percent crops used	53.3	11.7	32.8	2.0	0.2
Biomass (OD tons/acre)	1.31	1.17	1.94	1.68	0.82
Cost ^{a/} (\$/OD ton)	38.04	33.83	38.14	34.95	34.37

^{a/} Transportation costs not included

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
NEBRASKA-IOWA REGION

TABLE A-31

TOTAL BIOMASS

Crop area	2,834,100
Crop area used	259,425
Percent area used	9.2
Available biomass (OD tons)	2,219,881
Biomass used (OD tons)	220,000
Percent biomass used	9.9
Harvest costs ^{a/}	13.38
Nutr replacement cost ^{a/}	9.13
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	15.01
Transport cost ^{a/}	3.22
Total cost ^{a/}	40.89

^{a/} Average cost per oven dry ton

TABLE A-32

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>	<u>BAR</u>	<u>SGG</u>
Total acres	1,445,000	24,180	277,000	5,300	20,870
Acres used	195,015	23,480	37,800	2,600	530
Available biomass (OD tons)	1,621,214	28,329	536,154	8,912	2,003
Biomass used (OD tons)	222,561	27,532	75,087	4,438	383
Percent crops used	67.4	8.3	22.8	1.3	0.1
Biomass (OD tons/acre)	1.31	1.17	1.94	1.68	0.82
Cost ^{a/} (\$/OD ton)	38.04	33.83	38.14	34.95	34.37

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD TONS/DAY
NEBRASKA-IOWA REGION

TABLE A-33

TOTAL BIOMASS

Crop area	2,834,100
Crop area used	708,423
Percent area used	25.0
Available biomass (OD tons)	3,319,881
Biomass used (OD tons)	990,000
Percent biomass used	29.8
Harvest costs ^{a/}	13.38
Nutr replacement cost ^{a/}	9.29
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	15.11
Transport cost ^{a/}	4.29
Total cost ^{a/}	42.21

^{a/} Average cost per oven dry ton

TABLE A-34

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>	<u>BAR</u>	<u>SGG</u>
Total acres	1,445,000	24,180	277,000	5,300	20,870
Acres used	575,200	24,180	104,013	2,600	2,430
Available biomass (OD tons)	1,621,214	28,329	536,154	8,912	2,003
Biomass used (OD tons)	738,390	28,329	216,840	4,438	2,003
Percent crops used	4.6	2.9	21.9	0.4	0.2
Biomass (OD tons/acre)	1.31	1.17	1.94	1.68	0.82
Cost ^{a/} (\$/OD ton)	38.04	33.83	33.14	34.95	34.37

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
OREGON REGION

TABLE A-35

TOTAL BIOMASS

Crop area	698,200
Crop area used	98,684
Percent area used	14.1
Available biomass (OD tons)	1,525,987
Biomass used (OD tons)	165,000
Percent biomass used	10.8
Harvest costs ^{a/}	11.36
Nutr replacement cost ^{a/}	0.00
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	7.57
Transport cost ^{a/}	2.25
Total cost ^{a/}	21.33

^{a/} Average cost per oven dry ton

TABLE A-36

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>PSG</u>	<u>ASG</u>
Total acres	131,950	102,300
Acres used	54,084	44,600
Available biomass (OD tons)	220,621	171,046
Biomass used (OD tons)	90,429	74,571
Percent crops used	54.8	45.2
Biomass (OD tons/acre)	1.67	1.67
Cost ^{a/} (\$/OD ton)	19.07	19.07

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 1,000 OD TONS/DAY
OREGON REGION

TABLE A-37

TOTAL BIOMASS

Crop area	698,200
Crop area used	197,368
Percent area used	28.3
Available biomass (OD tons)	1,525,987
Biomass used (OD tons)	330,000
Percent biomass used	21.6
Harvest costs ^{a/}	11.36
Nutr replacement cost ^{a/}	0.00
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	7.57
Transport cost ^{a/}	2.90
Total cost ^{a/}	21.90

^{a/} Average cost per oven dry ton

TABLE A-38

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>PSG</u>	<u>ASG</u>
Total acres	131,950	102,300
Acres used	115,568	81,800
Available biomass (OD tons)	220,621	171,046
Biomass used (OD tons)	193,230	136,770
Percent crops used	58.6	41.4
Biomass (OD tons/acre)	1.67	1.67
Cost ^{a/} (\$/OD ton)	19.07	19.07

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 3,000 OD TONS/DAY
OREGON REGION

TABLE A-39

TOTAL BIOMASS

Crop area	698,200
Crop area used	442,377
Percent area used	63.4
Available biomass (OD tons)	1,525,987
Biomass used (OD tons)	990,000
Percent biomass used	64.9
Harvest costs ^{a/}	14.60
Nutr replacement cost ^{a/}	5.09
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	13.13
Transport cost ^{a/}	4.36
Total cost ^{a/}	37.33

^{a/} Average cost per oven dry ton

TABLE A-40

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>OAT</u>	<u>BAR</u>	<u>PSG</u>	<u>ASG</u>
Total acres	224,100	36,100	34,500	131,950	102,300
Acres used	165,727	16,300	26,100	131,950	102,300
Available biomass (OD tons)	695,050	64,347	82,552	220,621	171,046
Biomass used (OD tons)	504,984	28,726	64,624	220,621	171,046
Percent crops used	51.0	2.9	6.5	22.3	17.3
Biomass (OD tons/acre)	3.10	1.78	2.39	1.67	1.67
Cost ^{a/} (\$/OD ton)	41.77	45.83	42.70	19.07	19.07

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
RESIDUES - 500 OD TONS/DAY
TEXAS REGION

TABLE A-41

TOTAL BIOMASS

Crop area	482,960
Crop area used	142,543
Percent area used	29.5
Available biomass (OD tons)	178,129
Biomass used (OD tons)	165,000
Percent biomass used	92.6
Preharvest cost ^{a/}	1.68
Harvest costs ^{a/}	16.36
Nutr replacement cost ^{a/}	4.45
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	12.53
Transport cost ^{a/}	8.06
Total cost ^{a/}	43.21

^{a/} Average costs per oven dry ton

TABLE A-42

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>OAT</u>	<u>HAY</u>	<u>SGG</u>	<u>SGS</u>	<u>SGH</u>	<u>PEA</u>
Total acres	32,400	26,300	8,200	53,800	325,500	1,300	12,400	22,060
Acres used	19,400	16,200	8,200	44,600	27,700	300	6,533	19,610
Available biomass (OD tons)	36,923	15,244	7,285	51,997	20,138	6,584	18,428	21,530
Biomass used (OD tons)	36,923	15,244	7,285	51,997	20,138	1,411	10,473	21,530
Percent crops used	22.5	9.2	4.4	31.5	12.2	0.9	6.3	13.0
Biomass (OD tons/acre)	1.90	0.94	0.89	1.17	0.73	5.06	1.49	1.10
Cost ^{a/} (\$/OD ton)	39.70	35.60	39.45	30.38	35.97	42.35	42.35	32.38

^{a/} Transportation costs not included

APPENDIX B

MINIMUM COST BIOMASS, GRAINS

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
ARKANSAS REGION

TABLE B-1

TOTAL BIOMASS

Crop area	2,862,400
Crop area used	195,151
Percent area used	6.8
Available biomass (OD tons)	1,159,633
Biomass used (OD tons)	165,000
Percent biomass used	14.2
Preharvest cost ^{a/}	55.77
Harvest costs ^{a/}	6.94
Storage cost ^{a/}	
Indirect cost ^{a/}	57.63
Transport cost ^{a/}	5.66
Total cost ^{a/}	126.13

^{a/} Average cost per oven dry ton.

TABLE B-2

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>SGG</u>
Total acres	166,700	30,200
Acres used	164,951	30,200
Available biomass (OD tons)	129,679	36,803
Biomass used (OD tons)	128,197	36,803
Percent crops used	77.7	22.3
Biomass (OD tons/acre)	0.78	1.22
Cost ^{a/} (\$/OD ton)	130.28	86.32

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
CALIFORNIA REGION

TABLE B-3

TOTAL BIOMASS

Crop area	1,309,480
Crop area used	86,012
Percent area used	6.6
Available biomass (OD tons)	1,363,958
Biomass used (OD tons)	165,000
Percent biomass used	12.1
Preharvest cost ^{a/}	65.40
Harvest costs ^{a/}	4.75
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	61.48
Transport cost ^{a/}	2.76
Total cost ^{a/}	134.56

^{a/} Average cost per oven dry ton.

TABLE B-4

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>
Total acres	28,500	312,400
Acres used	9,000	77,012
Available biomass (OD tons)	59,987	480,917
Biomass used (OD tons)	18,846	146,154
Percent crops used	11.4	88.6
Biomass (OD tons/acre)	2.10	1.54
Cost ^{a/} (\$/OD ton)	132.61	131.65

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
GEORGIA REGION

TABLE B-5

TOTAL BIOMASS

Crop area	1,127,905
Crop area used	126,379
Percent area used	11.2
Available biomass (OD tons)	1,177,745
Biomass used (OD tons)	16,500
Percent biomass used	7.1
Preharvest cost ^{a/}	65.15
Harvest costs ^{a/}	9.78
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	55.89
Transport cost ^{a/}	3.27
Total cost ^{a/}	134.22

^{a/} Average cost per oven dry ton.

TABLE B-6

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>SGG</u>
Total acres	575,620	13,240
Acres used	113,139	13,240
Available biomass (OD tons)	764,085	13,316
Biomass used (OD tons)	151,684	13,316
Percent crops used	91.9	8.1
Biomass (OD tons/acre)	1.33	1.01
Cost ^{a/} (\$/OD ton)	133.85	98.04

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
ILLINOIS REGION

TABLE B-7

TOTAL BIOMASS

Crop area	3,016,600
Crop area used	51,434
Percent area used	1.7
Available biomass (OD tons)	5,563,116
Biomass used (OD tons)	165,000
Percent biomass used	3.0
Preharvest cost ^{a/}	27.89
Harvest costs ^{a/}	3.36
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	44.99
Transport cost ^{a/}	2.25
Total cost ^{a/}	78.63

^{a/} Average cost per oven dry ton.

TABLE B-8

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>
Total acres	1,672,100
Acres used	51,434
Available biomass (OD tons)	5,412,881
Biomass used (OD tons)	165,000
Percent crops used	100.0
Biomass (OD tons/acre)	3.24
Cost ^{a/} (\$/OD tons)	76.38

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
KANSAS REGION

TABLE B-9

TOTAL BIOMASS

Crop area	2,613,130
Crop area used	215,185
Percent area used	8.2
Available biomass (OD tons)	1,887,976
Biomass used (OD tons)	165,000
Percent biomass used	8.7
Preharvest cost ^{a/}	31.50
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	61.39
Transport cost ^{a/}	2.87
Total cost ^{a/}	103.07

^{a/} Average cost per oven dry ton.

TABLE B-10

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>WHT</u>	<u>BAR</u>
Total acres	35,400	1,702,400	10,100
Acres used	4,900	203,655	6,630
Available biomass (OD tons)	79,789	1,274,427	8,529
Biomass used (OD tons)	11,432	148,037	5,531
Percent crops used	6.9	89.7	3.4
Biomass (OD tons/acre)	2.25	0.75	0.84
Cost ^{a/} (\$/OD ton)	101.15	100.15	99.04

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
NEBRASKA-IOWA REGION

TABLE B-11

TOTAL BIOMASS

Crop area	2,834,100
Crop area used	106,742
Percent area used	3.8
Available biomass (OD tons)	2,709,298
Biomass used (OD tons)	165,000
Percent biomass used	6.1
Preharvest cost ^{a/}	33.92
Harvest costs ^{a/}	4.76
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	51.03
Transport cost ^{a/}	2.54
Total cost ^{a/}	92.38

^{a/} Average cost per oven dry ton.

TABLE B-12

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>SGG</u>
Total acres	144,500	20,870
Acres used	85,872	20,870
Available biomass (OD tons)	2,431,934	29,939
Biomass used (OD tons)	135,061	29,939
Percent crops used	81.9	18.1
Biomass (OD tons/acre)	1.68	1.43
Cost ^{a/} (\$/OD ton)	93.09	75.18

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
OREGON REGION

TABLE B-13

TOTAL BIOMASS

Crop area	698,200
Crop area used	102,959
Percent area used	14.7
Available biomass (OD tons)	691,089
Biomass used (OD tons)	165,000
Percent biomass used	23.9
Preharvest cost ^{a/}	45.97
Harvest costs ^{a/}	15.88
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	56.44
Transport cost ^{a/}	3.53
Total cost ^{a/}	121.94

^{a/} Average cost per oven dry ton.

TABLE B-14

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>WHT</u>	<u>OAT</u>
Total acres	224,100	36,100
Acres used	85,859	17,100
Available biomass (OD tons)	40,972	27,212
Biomass used (OD tons)	152,177	12,823
Percent crops used	92.2	7.8
Biomass (OD tons/acre)	1.79	0.75
Cost ^{a/} (\$/OD tons)	118.55	117.00

^{a/} Transportation costs not included.

MINIMUM COST ANALYSIS
GRAIN - 500 OD TONS/DAY
TEXAS REGION

TABLE B-15

TOTAL BIOMASS

Crop area	482,960
Crop area used	133,978
Percent area used	27.7
Available biomass (OD tons)	451,124
Biomass used (OD tons)	165,000
Percent biomass used	36.6
Preharvest cost ^{a/}	30.51
Harvest costs ^{a/}	5.15
Storage cost ^{a/}	0.14
Indirect cost ^{a/}	52.86
Transport cost ^{a/}	5.29
Total cost ^{a/}	93.95

^{a/} Average cost per oven dry ton.

TABLE B-16

AVAILABLE BIOMASS USED

<u>Crops</u>	<u>CRN</u>	<u>SGG</u>
Total acres	32,400	325,500
Acres used	32,400	101,578
Available biomass (OD tons)	59,609	350,981
Biomass used (OD tons)	59,609	105,391
Percent crops used	36.1	63.9
Biomass (OD tons/acre)	1.84	1.08
Cost ^{a/} (\$/OD ton)	74.03	96.92

^{a/} Transportation costs not included.