Biomass as Sustainable Energy: The Potential and Economic Impacts on U.S. Agriculture

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Working Paper 92-WP 92
April 1992

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This paper is based upon research conducted by CARD for SERI and for the DOE Office of Conservation and Renewable Energy.

Journal Paper No. 14862 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project No. 2872.

ABSTRACT

This paper addresses the economic feasibility and impacts on U.S. agriculture of establishing a biomass crops industry capable of producing 8 quads methanol or 9.4 quads ethanol by the year 2030 from grasses grown as biomass feedstocks. The results suggest that such an industry could become commercially viable and that the agricultural economy would benefit. Producers of traditional and biomass crops would benefit most. While consumers and livestock producers would be worse off as a result of higher crop prices, society would gain from reduced government payments to crop producers and from lower levels of air pollution.

I. INTRODUCTION

The recent Gulf crisis and a resuscitated public awareness of environmental problems have invigorated the debate on energy policy and renewable energy resources in the United States.[1] Among the most promising renewable energy technologies is fuel alcohol from biomass.[2] Alcohol, in the form of ethanol or methanol processed from the cellulose and hemicellulose portions of biomass, holds great potential as a cost-efficient alternative to fossil fuels (Sperling, 1988). Moreover, biomass is renewable and produces substantially lower carbon and sulfur emissions.[3]

Several issues, however, need to be resolved before biomass becomes a viable alternative energy resource. Among these issues are the economic impacts and feasibility of a biomass industry. The establishment of alcohol conversion plants, distribution systems, and biomass crop markets would significantly alter agriculture as well as the traditional energy industry.

This paper addresses the economic feasibility of a large U.S. biomass industry using the Basic Linked System (BLS),[4] an applied general equilibrium model, to simulate the world agricultural economy through the year 2030 under alternative biomass crop yield scenarios. We answer the following four fundamental questions:

1. *Would adequate profit incentives exist for biomass crop production to occur?* Yes: If biomass yield projections were fully realized, a biomass equivalent of 8 quads[5] could be produced profitably by 2030.

2. *How would production and profitability of livestock and traditional crops adjust?* The agricultural economy as a whole could profit from a large biomass industry. Although livestock producers would lose from higher feed prices, these losses would be more than offset by gains to producers of traditional and biomass crops.

3. *How would government payments to crop producers be affected?* The gains to crop producers would reduce government support program outlays.

4. *How would consumption and consumer prices of agricultural commodities adjust?* Generally, food product prices would rise and consumption would fall slightly.

Overall, our results suggest that the U.S. agriculture sector can accommodate a large biomass industry of more than one billion tons of biomass crop per year that could produce 8 quads methanol or 9.4 quads ethanol. The agriculture sector would benefit, and reliance on government program support might well decline.

The paper progresses as follows. Section II describes the conditions motivating this study. Sections III and IV describe methodology, conditioning assumptions, and alternative biomass scenarios in detail. Section V examines impacts on crop acreages, yields, and production; biomass and agricultural producer net returns; and government payments. Attention is also paid producer and consumer prices, and net gains and losses to agriculture, taxpayers, and consumers. The paper concludes with a discussion of policy implications.

II. BACKGROUND

Renewable energy technologies for residential, commercial, and industrial applications are substantially developed. Although economic, political, and social barriers exist, the prospect for widespread adoption of some of these technologies is promising. Of these, fuel alcohol from biomass has already been used for several years in the United States, Brazil, and elsewhere. Ethanol from grain, primarily corn, has been used commercially as an octane enhancer in gasoline for over a decade in the United States,[6] but most biofuel technologies have been considered commercially unfeasible.

It seems now, though, that alcohol fuels from domestic organic resources other than food or forestry crops could become commercially viable within a decade (Tyson et al., 1991). Research over the last decade at the Oak Ridge National Laboratories (ORNL) and at the Solar Energy Research Institute (SERI) has explored the technical potential of these biomass crops. ORNL's Herbaceous Energy Crop program concentrates on the production of energy sorghum, switchgrass, sudan grass, weeping lovegrass, sericea lespedeza, and other nonwoody feedstocks. SERI studies converting the cellulose and hemicellulose portions of these lignocellulosic feedstocks into fuel alcohol.

Once the demand for fuel alcohol develops, methanol and ethanol produced from these biomass crops will have commercial potential: the Midwestern, Plains, and Southeastern regions of the United States have appropriate climates and soils to produce large quantities of biomass at reasonable cost (Tyson et al., 1991). By 2030, up to 172 million acres of cropland could be idle in the United States under certain conditions (USDA-SCS, 1989); these idle acres could produce enough biomass to support an alcohol industry with a capacity of 8 quads methanol or 9.4 quads ethanol per year (SERI, 1990). At this level of production, significant increases could be expected in food, feed, and fiber prices as biomass and traditional crops compete for the same land resources.

Combined with energy-efficiency improvements, 8 quads ethanol could satisfy nearly half the projected U.S. demand for gasoline in the year 2030.[7] Once the commercial opportunities presented by biomass become evident, the costs and benefits to society arising from introduction of this technology into the economic structure—whether through competitive means or government intervention—require evaluation. The enormous costs of the Brazilian alcohol program since 1979 make it clear that land pattern changes, intraindustry impacts, government incentives, and profit potential are key issues in evaluating the supply side of biomass' economic potential (de Oliveira, 1991).

III. THE ECONOMIC MODEL

The present study applies the BLS as an analytical tool to explore the economic impacts of a U.S. biomass industry. The BLS national and regional models (Abkin, 1985, and Fisher, et al., 1988) comprise a system of applied general equilibrium models econometrically estimated with country-specific data and linked by policy and by an endogenous world price determination process. The BLS consists of 20 country models[8] and 14 regional models detailing the agricultural sectors of countries and regions while emphasizing food and agricultural policies. As an applied general equilibrium model, the BLS accommodates interdependencies and feedbacks that partial equilibrium economic models do not. These linkages include economic relationships between agricultural and nonagricultural sectors.

Parameterization of the model is restricted by standard economic theory: the supply components of the model are homogeneous of degree zero in prices, and demand components are homogeneous of degree zero in prices and income. The relations between world market prices and domestic prices are homothetic; that is, only relative prices matter. As a general equilibrium model, the BLS relates consumer expenditure to income generated by payments to factors of production. Additionally, the financial balance of a country with the rest of the world is explicitly represented.

The solution of the system provides a global agricultural balance sheet of commodity flows, and traces how these levels are influenced by policies. The system provides international trade flows and identifies domestic supply and demand forces determining exports and imports. The system can assess the impact on each country's domestic food situation of national government policies, as well as policies of other countries. Country policies can be evaluated in a global context by solving all the national models simultaneously or in a domestic context by solving all the national models in a stand-alone mode (in which world prices are exogenous). Consistency among physical flows of commodities and financial accounts of economic agents is ensured at national and global levels. These consistencies and the global coverage ensure that secondary effects and adjustments are reflected in BLS solutions.

Indicators generated by the BLS include *macroeconomic variables:* gross domestic product (GDP), GDP of the agricultural sector, GDP of the non-agricultural sector, value of net exports, value of net agricultural exports, trade surplus, a price index of nonagricultural production, and total agricultural and nonagricultural labor, agricultural and nonagricultural capital; *sectoral performance variables:* gross cash receipts for the agricultural sector, some measure of production cost and net farm income, total fertilizer use, and total cultivated area; and *commodity specific variables:* wholesale and retail prices, supply and utilization accounts, and input use. Because the BLS is a comprehensive general equilibrium model, the list of variables it generates is extensive. To accommodate space limitations, we focus our discussion on a few key indicator variables.

Because the United States is a major actor on world markets for agricultural commodities, a detailed national food and agricultural model has been developed for it. The U.S. model linked into the BLS has three important components: supply, demand, and agricultural policy. The main policies included in the U.S. model are commodity and dairy programs, and import restrictions. The commodity programs include target prices, set-aside requirements, and paid diversion programs.

The demand component consists of four subcomponents: human consumption, feed use, industrial consumption, and seed use and losses. On the supply side, the model endogenously determines crop acreage, crop yields, livestock production, breeding herd inventories, and input use.

IV. BASELINE and BIOMASS SCENARIOS

Baseline

The baseline scenario projects the status quo into the future. It is an outcome projected by the modeling system of world and national agricultural economies through 2030 based on the continuation of historical policies as embodied in estimated supply, demand, and price transmission equations. Results of the biomass scenarios are compared to this baseline to estimate impacts. Individual country components in the baseline have been thoroughly validated and the system has been calibrated to coincide as nearly as possible with historical data.

The main exogenous variables are population growth and labor participation rates, both of which are based on the United Nations' medium forecast (U.N., 1989). The time path of total labor force in a country is exogenous in any given year and does not change from the baseline scenario to the policy scenario. The allocation of total labor between agriculture and nonagriculture, however, is endogenous and responds to relative prices and income. Centrally planned economy models (CMEA and China) are guided by exogenous human consumption targets for planning and policy. These targets do not respond to economic factors in the models and are thus constant across scenarios.

The overall growth of the world economy is a crucial element in both the baseline scenario and the policy evaluations. Agricultural performance is quite dependent upon the development of the overall economy in that many current policies are designed to control production levels to achieve desired domestic prices. Economic growth reduces the force of such distortions. This dependence of agriculture on the general economy is particularly great over the long term, as the impacts of economic growth accumulate. Growth rates for most national models of the BLS are endogenously determined according to savings, which, in turn, depends upon only GDP and external technology change as conditioning assumptions.

The endogenously generated baseline projections are summarized in appendix Tables A.1 through A.5. Tables A.1 - A.3 summarize baseline projections for the United States whereas Tables A.4 and A.5 summarize baseline projections for world agricultural economic indicators. These indicators summarize the outcome for the BLS at selected years and are indicative of the underlying assumptions (policies, population, etc.) incorporated into the model specification.

Biomass Scenarios

Biomass production was modeled as forced reductions in the baseline projections of traditional crop acreage reported in Table A.2. The reduction estimates were constructed in an attempt to bracket possible future cropland changes for reiteration between the BLS model and a land use model, ARIMS,[9] to estimate changes in cropland use patterns, yields, and erosion.[10] ARIMS is a linear programming model capable of projecting land use patterns for a single point in time.

Two biomass scenarios -- a High Biomass Yield (HBY) scenario and a Low Biomass Yield (LBY) scenario -- assume that biomass crop yields reach 100 percent and 50 percent of projected yields, respectively (Tyson, et al., 1991).

The baseline projections of domestic crop acreage and yields, and of food, feed, and fiber demands were produced by BLS and then used in ARIMS to form the baseline scenarios for the milestone years 2000, 2010, 2020, and 2030. The basecases produced by ARIMS gave projections of idle cropland for the milestone years. The growing demand for cropland, from both biomass and traditional crop production, diminished the amount of idled land available over time. Seventy-five percent of the idle cropland was assumed to be perfectly mobile.

Mobility and biomass production assumptions operated in the following manner: A biomass-ethanol plant operator will attempt to ensure a supply of biomass from nearby farmers surrounding the plant through contracts, bids, or other marketing devices. Farmers producing biomass will do so on acres that would have been either idle or used to produce other crops. Any significant reduction in the supply of the other crops will cause prices to change in food, feed, and fiber markets. These price changes will induce farmers in other areas to expand production of the other crops by bringing idle acres into production or by altering planting decisions. Yields for the various crops will also change as planting decisions are altered.

Biomass demands for the milestone years were derived from DOE projections (SERI, 1990). Demand was assumed to grow at a constant rate between milestone years, but not necessarily at a constant rate throughout the 40 years. These demands were divided by projected biomass yields to arrive at estimated annual land requirements for each scenario. When biomass demand for land exceeded 75 percent of idle acreage for that year, traditional crop acreage was reduced to reflect diversions of the land to biomass production. The reductions in total crop acreage were then allocated across major crops by region. Planted acreage for a specific crops (wheat, corn, etc.) was reduced in proportion to that crop's regional distribution. Traditional crop acreage reductions were assumed to be concentrated in the Corn Belt and the South and to a lesser extent in the Great Plains.

The diversion of traditional crop acreage to biomass production was modeled in the BLS as forced reductions in projected acreages of the traditional crops. Any growth in traditional crop acreage that would otherwise have occurred was included in the forced reductions. Traditional cropland reduction is thus the sum of diversions and of projected future growth that would otherwise have occurred.

As Table 1 indicates, the diversion of cropland to accommodate biomass production increased steadily in the HBY scenario to about 25 million hectares and to roughly 45 million hectares in the LBY scenario by the year 2030. Lower biomass yields require more land to meet the goal of 8 quads biomass alcohol production in 2030 and competition with traditional cropland begins earlier—in 2010 for the LBY scenario versus 2015 for the HBY scenario.

Table 1. Reductions of major cropland acreages resulting from biomass competition, millions of hectares

Year	Corn	Wheat	Soybeans	Oats	Barley	Sorghum	Rice	Cotton	Total
Low Biomass Yield Scenario (LBY)									
2010	0.84	0.53	0.69	0.02	0.03	0.14	0.02	0.06	2.33
2011	1.21	0.70	0.81	0.04	0.05	0.24	0.04	0.11	3.20
2012	1.93	1.48	1.27	0.05	0.08	0.35	0.06	0.14	5.35
2013	2.26	1.51	1.40	0.07	0.10	0.47	0.08	0.20	6.09
2014	2.90	2.15	2.00	0.09	0.13	0.59	0.10	0.24	8.19
2015	3.27	2.21	2.18	0.11	0.16	0.72	0.11	0.32	9.07
2016	4.08	3.10	2.75	0.13	0.19	0.86	0.14	0.36	11.60
2017	4.59	3.01	2.95	0.15	0.22	1.01	0.15	0.44	12.51
2018	5.18	3.87	3.60	0.18	0.25	1.17	0.17	0.49	14.91
2019	5.71	3.80	3.75	0.20	0.29	1.34	0.19	0.58	15.86
2020	6.47	4.63	4.54	0.23	0.33	1.51	0.21	0.64	18.56
2021	6.96	4.67	4.84	0.26	0.37	1.70	0.23	0.75	19.77
2022	7.86	5.73	5.62	0.29	0.42	1.91	0.25	0.82	22.89
2023	8.51	5.61	5.99	0.32	0.47	2.13	0.27	0.93	24.22
2024	9.32	6.58	6.80	0.36	0.52	2.36	0.29	1.03	27.25
2025	10.06	6.69	7.25	0.40	0.57	2.61	0.30	1.15	29.03
2026	11.08	7.79	8.19	0.44	0.63	2.88	0.33	1.26	32.59
2027	11.10	6.92	8.77	0.48	0.69	3.16	0.35	1.43	32.90
2028	12.58	8.42	9.92	0.53	0.76	3.46	0.37	1.54	37.57
2029	13.52	8.82	10.40	0.57	0.83	3.79	0.39	1.71	40.02
2030	15.00	10.27	11.59	0.62	0.90	4.12	0.40	1.84	44.75

Table 1 (continued)

Year	Corn	Wheat	Soybeans	Oats	Barley	Sorghum	Rice	Cotton	Total
High Biomass Yield Scenario (HBY)									
2015	0.08	0.11	0.06	0.00	0.00	0.02	0.02	0.02	0.31
2016	0.78	0.07	0.42	0.01	0.02	0.10	0.04	0.03	1.47
2017	1.16	0.49	0.52	0.02	0.04	0.18	0.06	0.08	2.55
2018	1.63	1.23	1.07	0.04	0.06	0.27	0.08	0.11	4.47
2019	2.02	1.04	1.11	0.05	0.08	0.36	0.09	0.16	4.91
2020	2.70	1.76	1.85	0.06	0.11	0.48	0.12	0.20	7.28
2021	3.03	1.66	2.02	0.08	0.14	0.59	0.13	0.27	7.91
2022	3.75	2.57	2.67	0.09	0.16	0.70	0.15	0.30	10.40
2023	4.23	2.29	2.89	0.11	0.19	0.82	0.17	0.37	11.07
2024	4.84	3.09	3.55	0.13	0.22	0.96	0.19	0.42	13.40
2025	5.37	3.01	3.84	0.14	0.25	1.09	0.21	0.49	14.42
2026	6.18	3.93	4.61	0.16	0.29	1.24	0.23	0.54	17.18
2027	5.95	2.85	5.01	0.18	0.33	1.40	0.25	0.66	16.63
2028	7.18	4.12	5.96	0.21	0.36	1.57	0.27	0.71	20.38
2029	7.85	4.28	6.23	0.23	0.41	1.75	0.29	0.81	21.86
2030	8.99	5.46	7.15	0.25	0.45	1.91	0.31	0.86	25.39

V. DISCUSSION

The results are encouraging for producers of both biomass and traditional crops. Livestock producers and food consumers do not fare as well, but part of the loss to consumers is recaptured by taxpayers through reduced government outlays for farm program payments.

At $34 per dry ton, the DOE goal for a market price covering total costs of the average biomass crop producer, HBY becomes the only operative scenario. None of the potential biomass crops in the LBY scenario can earn a positive net return over variable cost investments at a market price of $34 per dry ton. An industry will not exist if biomass yields are only half the DOE yield goals and alcohol processors cannot afford to offer more than $34 per dry ton for feedstock. However, the exercise of examining the international impacts of the LBY scenario illuminates the scope of impacts should land use requirements exceed those projected by the HBY scenario for any reason.

Results for the United States are presented in Tables 2 through 4 as percentage differences between the biomass scenarios and the baseline. U.S. macroeconomic and world results are not presented,[11] but indicate that the value of agricultural production rises in relation to nonagricultural production through 2030, especially in the United States. This effect follows mainly from an increase in agricultural prices.

Crop Production and Prices

Table 2 shows the impacts on U.S. crop acreages and yields for both scenarios, beginning in 2015. The status quo is maintained until then because the biomass sector does not compete significantly with traditional crops for land before 2010. Crop yields increase after the introduction of the biomass sector, reflecting an increase in crop prices. Incorporating biomass acreage into the model decreases the acres planted for most crops once competition for cropland begins. The reduction in acres planted of these traditional crops is actually less than reported in Table 1, however, because acres planted are endogenously determined in the model and because higher crop prices in the biomass scenarios induce a conversion of nonagricultural land to crop production.

Table 2. Percentage changes from baseline in U.S. crop acres & yields

Year	Wheat	Rice	Corn	Grain	Soybean	Cotton
U.S. crop acreages						
LBY: 2015	-3.21	-6.69	-5.86	-5.39	-6.42	-4.24
2020	-7.24	-15.24	-13.31	-16.50	-14.65	-10.43
2025	-10.58	-22.62	-23.73	-34.43	-23.82	-18.91
2030	-14.16	-29.25	-35.69	-46.76	-26.85	-31.04
HBY: 2015	0.07	-0.22	-0.03	-0.03	0.03	-0.07
2020	-1.84	-6.32	-4.13	-2.98	-4.09	-2.51
2025	-4.45	-14.21	-11.16	-11.55	-12.62	-7.72
2030	-6.94	-21.65	-19.67	-24.48	-20.68	-15.09
U.S. crop yields						
LBY: 2015	0.14	5.48	0.23	-0.79	0.28	0.10
2020	0.28	12.70	0.46	-2.93	0.61	0.28
2025	0.45	20.16	0.60	-8.99	0.96	0.49
2030	0.80	28.73	1.16	-20.22	2.01	0.91
HBY: 2015	0.00	0.22	0.00	0.00	0.00	0.00
2020	0.07	5.13	0.14	-0.45	0.15	0.06
2025	0.22	11.62	0.31	-1.96	0.46	0.21
2030	0.41	19.12	0.64	-6.21	1.03	0.42

Table 3 presents the relative impacts on U.S. production, net exports, domestic use, stocks, and retail prices for nine commodities, including nonagriculture. The combination of acreage reductions and yield changes cause a decline in all traditional crop production in the biomass scenarios (Figure 1). Coarse grain production, primarily corn and sorghum, suffers the greatest decline: 20 percent in 2030. Because of lowered production, prices for crop products increase in the biomass scenarios (Figure 2). Note that prices are influenced by domestic and foreign production as well as by domestic and foreign demand. In the BLS, U.S. wheat production could decline, but bumper crops overseas could mitigate these price increases. Thus, even though crop bases and crop production fall because biomass competes for cropland resources, domestic market prices might not change greatly if conditions are favorable for higher overseas production.

Table 3. Percentage changes from baseline in U.S. agricultural production variables

	Year	Wheat	Rice	Coarse grain	Bovine & ovine	Dairy	Other animal	Protein feed	Other food	Nonfood agriculture	Nonagri-culture
U.S. production											
LBY:	2015	-3.09	-1.61	-5.72	0.26	-0.15	-1.17	-6.15	-1.45	-0.98	-0.01
	2020	-6.99	-4.51	-13.72	0.56	-0.30	-3.40	-14.10	-3.62	-2.40	-0.06
	2025	-10.19	-7.05	-25.51	0.83	-0.41	-6.14	-23.07	-6.18	-4.39	-0.14
	2030	-13.47	-8.96	-37.91	1.24	-0.56	-9.82	-25.51	-6.85	-7.24	-0.28
HBY:	2015	0.07	0.00	-0.03	0.00	0.00	0.01	0.03	0.01	-0.02	0.00
	2020	-1.78	-1.55	-3.94	0.14	-0.08	-0.59	-3.95	-0.95	-0.58	-0.01
	2025	-4.25	-4.27	-11.22	0.41	-0.21	-2.52	-12.17	-3.05	-1.77	-0.04
	2030	-6.57	-6.70	-20.49	0.73	-0.37	-5.20	-19.83	-5.14	-3.47	-0.11
U.S. net exports											
LBY:	2015	-4.91	-1.83	-13.73	0.16	2.47	-77.64	-9.58	-10.17	1.61	-7.07
	2020	-10.61	-5.22	-30.73	0.53	2.78	107.65	-21.91	-26.30	1.56	-19.08
	2025	-13.99	-8.21	-53.15	1.11	2.45	93.84	-34.03	-44.14	3.09	-47.51
	2030	-14.70	-9.33	-85.54	2.14	7.49	128.13	-34.74	-44.12	4.51	-53.18
HBY:	2015	0.07	0.01	-0.11	0.01	0.07	1.31	0.05	0.09	-0.04	0.00
	2020	-3.42	-1.75	-8.83	0.08	1.18	15.86	-6.03	-6.59	0.74	-3.25
	2025	-6.18	-4.92	-23.17	0.40	1.67	36.26	-18.56	-21.47	0.91	-16.15
	2030	-7.95	-7.23	-45.44	1.03	3.46	65.28	-29.45	-33.13	2.86	-28.88
U.S. domestic use											
LBY:	2015	0.15	-1.11	-2.26	0.25	-0.35	-0.52	-1.97	-0.12	-1.02	-0.02
	2020	-1.15	-2.84	-5.41	0.56	-0.73	-1.38	-4.42	-0.20	-2.50	-0.09
	2025	-2.40	-4.36	-9.47	0.86	-1.17	-2.32	-8.90	-0.33	-4.63	-0.19
	2030	-13.17	-6.72	-14.83	1.32	-1.93	-3.37	-13.66	-0.56	-7.71	-0.35
HBY:	2015	0.09	-0.02	-0.02	0.00	0.00	0.00	0.01	0.00	-0.02	0.00
	2020	1.15	-1.05	-1.46	0.14	-0.20	-0.28	-1.25	-0.09	-0.60	-0.01
	2025	-0.21	-2.68	-4.23	0.41	-0.57	-1.03	-3.85	-0.21	-1.86	-0.06
	2030	-5.21	-4.54	-7.94	0.76	-1.07	-1.92	-7.11	-0.38	-3.69	-0.15
U.S. stocks											
LBY:	2015	-1.75	-4.42	-2.70	NA	-6.16	-7.28	-6.18	-6.18	-4.22	NA
	2020	-1.57	-6.31	-1.75	NA	-8.61	-15.24	-14.16	-14.15	-6.42	NA
	2025	-2.83	-7.59	0.15	NA	-6.22	-6.79	-23.10	-23.11	-11.52	NA
	2030	-2.62	-25.25	28.42	NA	-9.99	-4.61	-25.29	-25.30	-17.46	NA
HBY:	2015	0.02	-0.06	-0.02	NA	-0.02	-0.75	0.04	0.04	0.08	NA
	2020	-1.46	-3.24	-3.03	NA	-4.06	-7.36	-3.97	-3.97	-2.92	NA
	2025	-2.67	-5.61	-4.35	NA	-6.21	-10.77	-12.24	-12.24	-4.96	NA
	2030	-1.76	-19.88	8.65	NA	-8.18	-8.20	-19.88	-19.88	-9.47	NA

Table 3. (continued)

	Year	Wheat	Rice	Coarse grain	Bovine & ovine	Dairy	Other animal	Protein feed	Other food	Nonfood agriculture	Nonagri-culture
U.S. retail prices											
LBY:	2015	3.18	1.27	1.33	0.48	1.52	1.35	12.65	0.36	0.46	-1.94
	2020	6.90	2.85	3.92	1.32	3.28	3.52	26.38	0.58	1.36	-3.98
	2025	12.49	4.71	7.70	2.41	5.49	6.06	51.25	1.10	2.94	-6.46
	2030	20.79	12.74	12.07	3.69	9.23	9.13	70.06	2.53	5.73	-10.51
HBY:	2015	0.01	0.01	0.00	0.00	0.01	-0.01	-0.03	0.00	0.01	0.02
	2020	1.75	0.72	0.75	0.28	0.85	0.74	8.20	0.25	0.25	-1.28
	2025	5.80	2.19	2.81	1.06	2.60	2.69	24.00	0.64	1.04	-3.20
	2030	10.44	5.25	5.73	2.02	4.97	5.08	40.98	1.35	2.38	-6.00

Livestock Production and Prices

As expected, higher feed grain price cause production of dairy, pork and poultry to decrease and the production of beef to increase. After an initial drop, livestock prices also increase after the introduction of biomass crops.

Consumer, Export, and Feed Demand

Lower production and higher crop prices resulted in a reduced demand for crop products (Figure 3). Specifically, the net exports, food, and feed demands for crop products are smaller in the biomass scenario. Demand reductions are highest in coarse grain and protein feeds sectors. The effects on livestock demand are mixed. While the consumption of pork, poultry, and milk products falls slightly, the consumption of beef changes little.

Farm Profitability and Government Payments

Table 4 summarizes the impacts on farm profitability for the HBY scenario in the milestone years 2020 and 2030. Estimates of net farm income and of government payments were made using the prices and trends suggested by the BLS results for the baseline and HBY scenarios.

Table 4. Estimated changes in farm income and government payments for milestone years 2020 and 2030 in millions of 1989 dollars, high biomass yields (HBY) scenario

	Food, Feed, & Fiber Crops		Livestock Poultry Dairy	Biomass Crops	Total Agricultural Commodities
Year	Net Crop Returns	Government Transfer Payments	Net Product Returns	Net Crop Returns[a]	Government & Commodity Income
2020	1317	-1368	-1392	5004	3560
2030	5037	-5548	-6465	10273	3297

[a] Assumes biomass Price equals $34 per dry ton.

Table 4 presents the absolute changes in net returns from livestock production, traditional crops, and biomass crops and the estimated changes in government transfer payments to agricultural crop producers.

The net returns to biomass production were estimated using a DOE target price of $34 per dry ton, a price at which the average biomass crop producer should be able to recover variable costs. Annual net returns to traditional crop producers increase through 2030 as commodity prices rise to compensate for lower crop production. These increases in net returns, though, are more than offset by reductions in government payments for set-aside and diversion programs, but crop producers are left relatively unaffected by the net changes in income source. As the biomass sector grows in size, net product returns from livestock production fall as feed grain prices increase. For the agriculture sector as a whole, however, the net gain in returns from biomass crop production more than offsets any losses in traditional crop or livestock production.

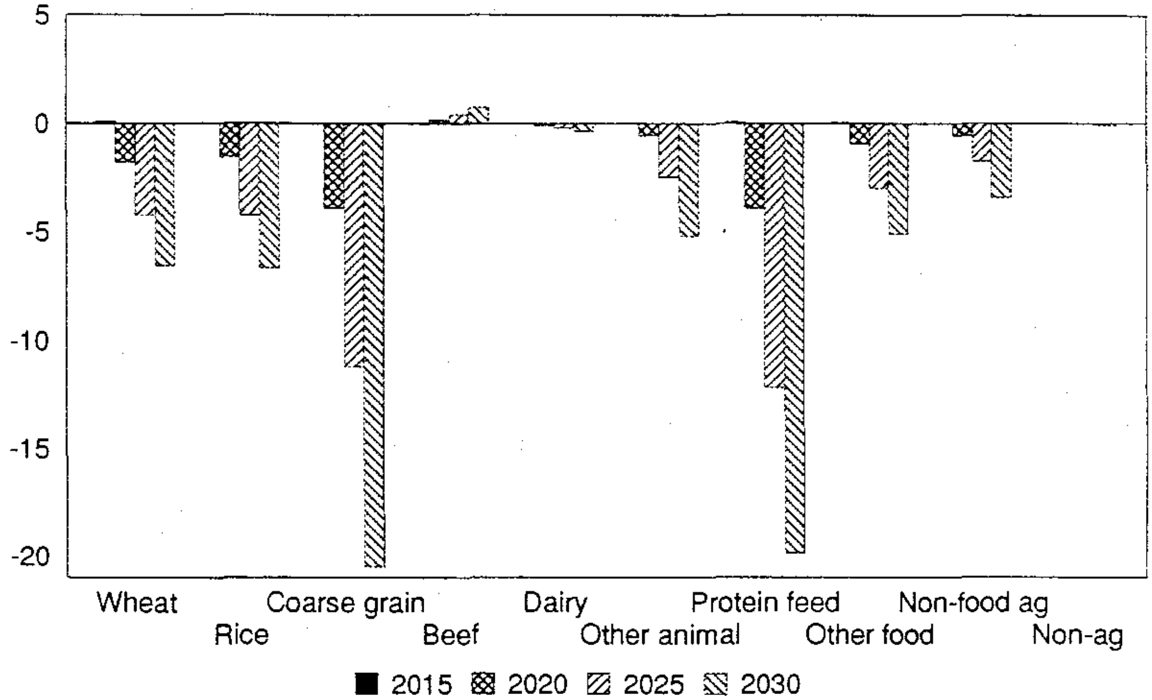

Figure 1. Percentage Changes from Baseline in Production (HBY)

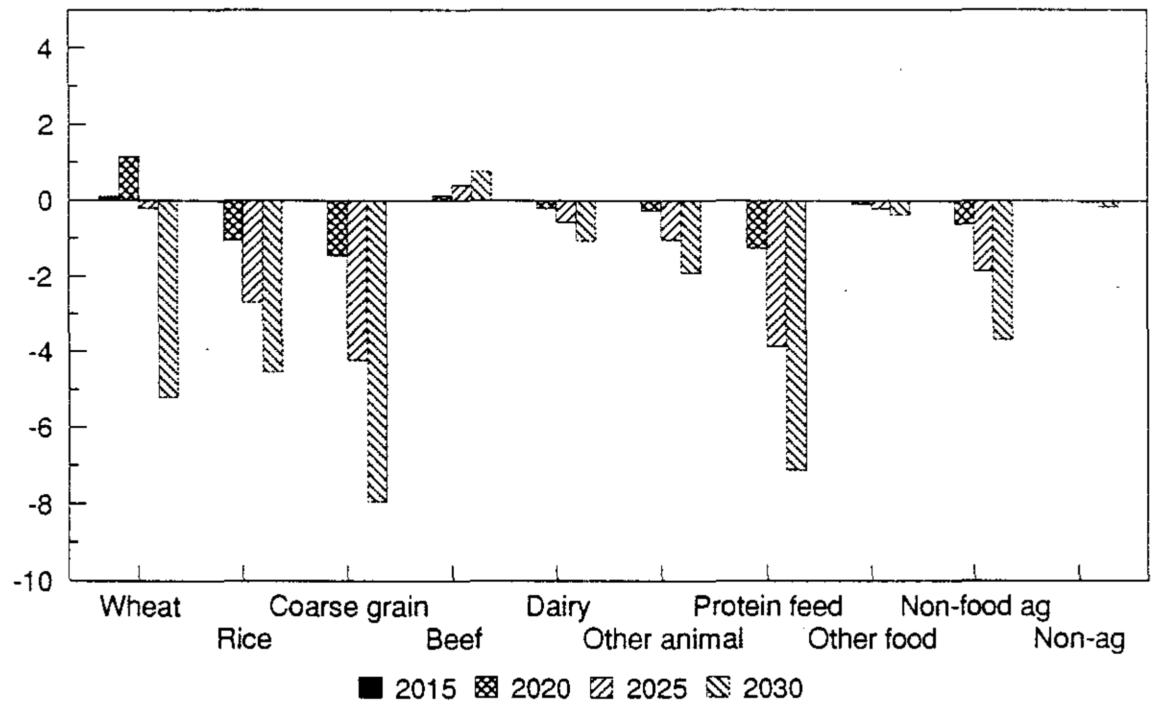

Figure 2. Percentage Changes from Baseline in Domestic Use (HBY)

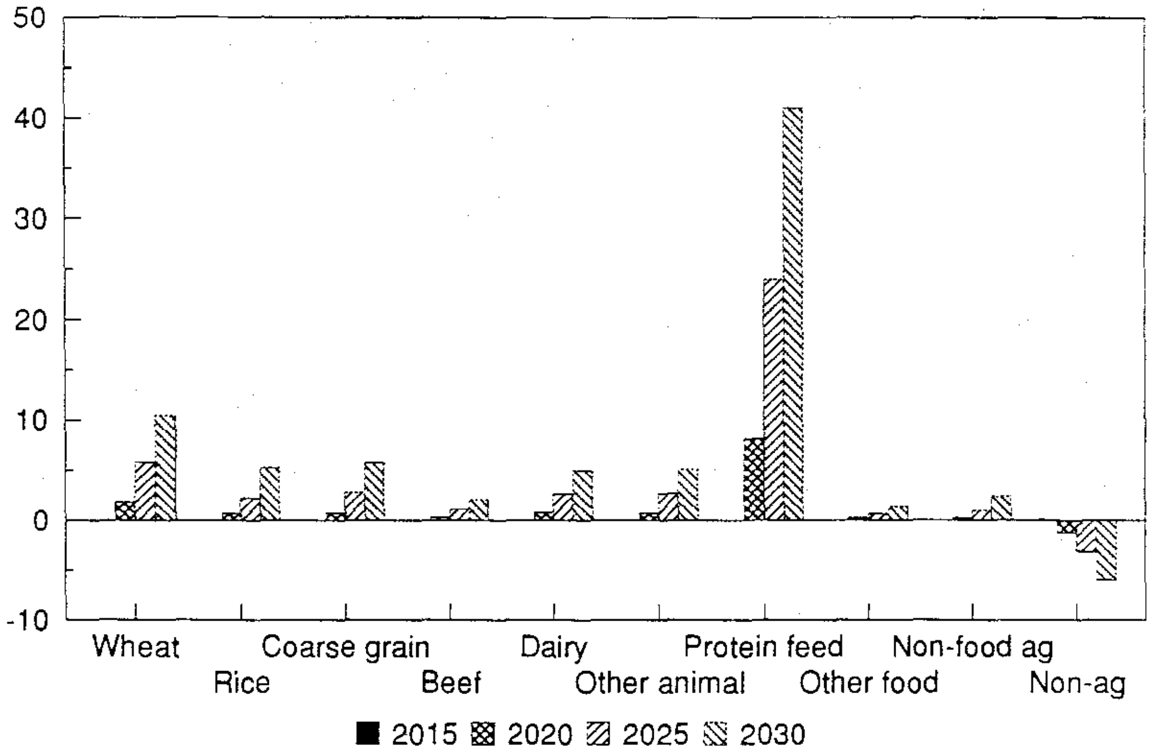

Figure 3. Percentage changes from baseline in relative prices

V. CONCLUSIONS AND POLICY RECOMMENDATIONS

Our results suggest that the U.S. agricultural sector and the U.S. economy as a whole is flexible enough to accommodate a large biomass industry (more than a billion tons per year), producing 8 quads methanol or 9.4 quads ethanol annually. None of the potential impacts presented here suggests major obstacles to the establishment or expansion of a biomass industry before the year 2030.

Overall, the U.S. agriculture sector should benefit from a healthy biomass industry. The analysis indicates that biomass production would contribute to large increases in farm income levels and lead to reductions in USDA farm program costs. These gains would probably not be uniform across the country, and some regions—those best suited for biomass crops production—would benefit more than others.

If biomass and biomass-alcohol industries become commercially feasible in the near future, U.S. agricultural programs, e.g., commodity price and income supports, and land diversion payments, will need to be reevaluated to reflect the expanded opportunities available to farmers. Overproduction issues would fade. New issues such as adequate stocks or supplies of key commodities, continued progress in yield-improving technologies, and import barriers to foreign alcohol supplies could emerge.

A new industry does not emerge without growing pains. Many issues will need to be addressed in the near future as the commercial potential of biomass becomes evident: how to protect an infant industry from price competition (crude oil price reductions caused by retaliatory pricing and declining demand for petroleum products) and instability; what the risks are to agricultural industries from climate changes; how to provide timely information to agricultural extension services and farmers about biomass species suitability, production techniques, and optimal harvesting times; and other issues vital to building a successful industry. The emergence of a new agricultural industry will provide many opportunities and challenges.

Appendix: Macroeconomic Effects and Baseline Values for the U.S. and World Markets

Table A.1. Percentage changes from baseline in U.S. macro variables

Year	GDP	GDP agriculture	Agriculture net imports	Price index agriculture to nonagriculture	Total crops acreage
	million $ 1970			1970=1	million ha
1990	1788.01	30.43	-8.36	1.250	133.94
1995	2072.00	32.20	-9.06	1.167	135.26
2000	2378.42	33.97	-10.28	1.278	138.20
2005	2707.25	35.37	-11.31	1.286	139.29
2010	3060.88	36.61	-12.36	1.311	142.46
2015	3441.93	37.78	-13.84	1.335	145.00
2020	3853.00	38.97	-14.81	1.338	147.65
2025	4296.94	40.08	-16.45	1.345	149.62
2030	4775.70	41.20	-17.25	1.318	151.56

Table A.2. Baseline values of US acreages and yields

Year	Wheat	Rice	Corn	Grain	Soybean	Cotton
US crop acreages						
	thousand hectares					
1990	29080.2	1069.2	28959.6	14982.0	23896.2	4491.0
1995	31594.4	1211.4	29722.0	13263.0	23146.0	4957.4
2000	32269.8	1192.4	30077.8	13418.0	24729.6	5185.6
2005	31779.0	1285.1	30579.6	13563.4	25572.2	5230.1
2010	33221.6	1378.7	31698.2	13732.8	25988.8	5205.2
2015	34266.2	1474.3	32722.2	13878.0	26326.2	5156.8
2020	35330.0	1570.3	33735.6	14059.8	26731.4	5097.4
2025	36112.2	1665.7	34478.0	14181.0	27071.2	5035.7
2030	36773.8	1764.8	34997.8	14347.0	27670.0	4965.8
US crop yields						
	metric tons per hectare					
1990	2.08	4.58	6.43	2.33	2.12	0.68
1995	2.24	4.64	7.22	2.57	2.39	0.68
2000	2.33	5.20	7.81	2.70	2.53	0.72
2005	2.43	5.41	8.16	2.82	2.63	0.74
2010	2.52	5.58	8.45	2.97	2.73	0.76
2015	2.61	5.74	8.72	3.11	2.82	0.77
2020	2.69	5.90	8.98	3.25	2.90	0.79
2025	2.77	6.06	9.22	3.39	2.99	0.82
2030	2.84	6.21	9.45	3.53	3.07	0.85

Table A.3. Baseline values of U.S. agricultural production variables

Year	Wheat	Rice	Coarse grain	Bovine & ovine	Dairy	Other animal	Protein feed	Other food	Nonfood agriculture	Nonagri-culture
	thousand metric tons							million $ 1970		
U.S. production										
1990	60422.2	3262.5	221518.6	9605.4	62239.0	2417.9	17111.0	13608.8	2453.9	3607469.8
1995	70631.8	3765.4	248667.4	9711.8	66470.0	2654.6	18685.4	13913.8	2591.7	4186728.0
2000	75183.8	4156.6	270996.8	9851.2	71590.2	2762.8	21088.0	14651.6	2736.8	4812034.6
2005	77189.6	4659.0	287751.6	9912.0	76868.0	2886.8	22652.6	15181.6	2847.0	5484095.2
2010	83747.0	5151.1	308597.0	10074.6	81987.6	2907.8	23797.4	15635.0	2939.9	6207383.4
2015	89343.0	5668.7	328610.8	10266.0	87122.2	2915.8	24860.8	16059.2	3022.7	6987088.6
2020	94991.8	6206.3	348660.8	10485.0	92223.0	2911.1	25991.6	16512.6	3110.8	7828381.0
2025	99863.4	6759.2	366011.4	10709.4	97378.4	2908.4	27071.0	16894.4	3205.9	8737294.4
2030	104343.6	7346.3	381209.0	10933.2	102521.4	2911.0	28402.8	17367.6	3277.2	9717664.2
U.S. net exports										
1990	33907.6	1898.5	48098.0	-1034.9	-1594.2	129.8	8489.8	2092.3	-17.5	11876.4
1995	46054.0	2331.0	66322.4	-1014.3	-1744.0	188.8	8953.8	1732.6	-3.3	8803.6
2000	46199.6	2631.8	69244.8	-993.0	207.6	168.2	10784.8	2017.6	12.6	3870.0
2005	47933.0	3069.1	75696.2	-999.6	2810.8	167.7	11826.8	2032.8	33.4	-6139.4
2010	52165.6	3458.8	88850.6	-1034.8	6011.8	98.8	12599.8	2053.8	53.2	-10965.4
2015	56879.2	3896.4	103136.4	-1073.7	8659.0	24.0	13448.6	2099.4	66.6	-9286.8
2020	59982.4	4324.8	116677.4	-1072.8	12030.0	-53.6	14258.8	2154.7	88.9	-12049.6
2025	64616.6	4818.3	129694.8	-1110.8	15106.8	-117.1	15146.6	2243.4	105.0	-9249.6
2030	66759.4	5316.9	136954.4	-1117.1	19572.6	-141.3	16131.2	2520.2	146.0	-12420.4
U.S. domestic use										
1990	24370.0	1344.5	169890.0	10640.4	63342.8	2285.3	8635.4	11518.6	2473.5	3595593.8
1995	26597.6	1448.5	194304.4	10726.4	68619.4	2465.4	9715.6	12178.8	2592.3	4177924.6
2000	27934.4	1515.5	200377.2	10844.2	70766.8	2594.3	10280.8	12630.8	2723.8	4808164.4
2005	29528.2	1591.7	212696.2	10912.0	73962.4	2719.4	10813.8	13147.2	2812.8	5490234.6
2010	31299.2	1684.8	219484.4	11109.8	76058.8	2809.0	11184.0	13579.2	2887.4	6218349.0
2015	32773.2	1777.7	226064.8	11339.8	78266.2	2891.8	11403.4	13958.6	2953.9	6996375.6
2020	34569.8	1868.9	231121.0	11557.8	80252.8	2964.5	11720.2	14356.0	3023.6	7840430.8
2025	35657.6	1953.1	237101.6	11820.4	82082.8	3024.9	11914.8	14649.6	3097.7	8746544.0
2030	36803.4	2020.5	242465.8	12050.4	82968.6	3052.0	12255.2	14845.0	3134.0	9730085.0

Table A.3 (continued)

Year	Wheat	Rice	Coarse grain	Bovine & ovine	Dairy	Other animal	Protein feed	Other food	Nonfood agriculture	Nonagri-culture
	thousand metric tons							million $ 1970		
U.S. stocks										
1990	20949.0	39.0	46150.2	0.0	1670.8	12.4	830.5	125.9	60.4	0.0
1995	19728.2	34.6	37623.8	0.0	3883.4	23.6	907.7	137.6	75.2	0.0
2000	21505.0	38.7	31883.0	0.0	3417.5	20.2	1026.1	155.6	59.7	0.0
2005	19306.0	78.9	29149.6	0.0	4175.2	21.0	1104.1	167.4	64.1	0.0
2010	19967.6	88.9	29533.4	0.0	4285.2	20.6	1161.7	176.1	65.1	0.0
2015	19686.6	91.9	29166.2	0.0	4737.7	20.1	1215.5	184.3	69.4	0.0
2020	20287.8	111.8	30192.8	0.0	4976.2	20.6	1272.3	192.9	70.5	0.0
2025	19777.4	108.2	29420.0	0.0	5523.2	22.4	1326.1	201.0	76.6	0.0
2030	20660.4	127.3	31375.2	0.0	5860.0	24.7	1393.0	211.2	75.9	0.0
U.S. retail prices					1970 = 1					
1990	1.180	1.394	1.174	2.223	1.034	1.311	1.405	1.053	1.525	0.596
1995	1.015	1.448	1.189	2.418	0.906	1.306	1.276	1.022	1.591	0.620
2000	1.097	1.628	1.228	2.654	0.987	1.357	1.305	1.059	1.607	0.586
2005	1.061	1.737	1.256	2.816	0.970	1.368	1.316	1.048	1.621	0.587
2010	1.079	1.765	1.291	2.929	0.984	1.393	1.318	1.052	1.625	0.581
2015	1.097	1.784	1.329	2.998	0.990	1.408	1.337	1.059	1.620	0.575
2020	1.106	1.784	1.367	3.041	0.994	1.415	1.318	1.053	1.606	0.577
2025	1.111	1.794	1.401	3.037	0.990	1.413	1.326	1.052	1.585	0.577
2030	1.093	1.802	1.423	2.982	0.984	1.400	1.276	1.038	1.557	0.585

Table A.4. Baseline values of world macro variables

Year	GDP	GDP agriculture	Price index agriculture to nonagriculture
	---------- million $ 1970 ------------		1970=1
1990	8593.04	433.00	1.26
1995	10081.27	475.27	1.16
2000	11716.80	517.46	1.27
2005	13450.31	559.95	1.27
2010	15270.85	604.75	1.26
2015	17183.66	649.44	1.31
2020	19198.25	696.78	1.28
2025	21319.00	742.97	1.31
2030	23552.31	792.31	1.27

Table A.5. Baseline values of world agricultural production variables

Year	Wheat	Rice	Coarse grain	Bovine & ovine	Dairy	Other animal	Protein feed	Other food	Nonfood agriculture	Nonagri-culture
	thousand metric tons							million $ 1970		
World production										
1990	523435.6	290865.2	788144.0	68962.0	528189.0	20276.6	43868.2	275591.0	27803.2	8160039.2
1995	558493.2	318157.0	863160.6	74556.2	569531.8	22756.4	48365.0	303797.6	29873.0	9606002.2
2000	605297.2	350720.6	937001.2	79351.8	604321.4	24967.2	53356.4	332489.0	31865.8	11199338.0
2005	636825.0	384390.4	1006396.6	84618.2	641371.8	27215.6	57666.4	362516.6	33919.4	12890360.0
2010	679118.6	413855.0	1078083.0	89694.8	676427.4	29282.4	61860.2	397212.4	35839.0	14666100.0
2015	717378.4	444104.0	1150937.4	95761.4	717857.0	31375.4	66028.8	430368.0	37851.0	16534218.0
2020	756500.8	475134.4	1225150.6	100993.4	756825.4	33467.6	70266.0	468227.6	39722.6	18501474.0
2025	794897.2	506276.6	1292541.6	106982.0	801755.8	35623.8	74454.6	503301.0	41748.4	20576026.0
2030	832001.2	540170.0	1359131.8	112175.0	844511.6	37781.6	78792.4	543805.4	43560.4	22760006.0
World net exports										
1990	107195.8	13076.0	119688.0	4785.2	26015.0	630.4	14485.6	23770.4	5576.8	56433.6
1995	126391.8	11481.4	138370.8	5657.6	30701.2	773.5	16005.6	24906.8	5790.9	55320.2
2000	132530.4	15219.8	144806.4	6061.2	30059.8	916.5	18125.8	27481.8	6010.8	58834.6
2005	139250.0	21317.4	148563.0	6854.6	34345.6	1105.9	19795.4	29891.2	6316.6	67653.8
2010	148564.2	24661.2	156888.4	7562.0	38782.2	1277.4	21355.2	32762.4	6679.4	75565.2
2015	158800.4	27175.2	168249.4	8803.8	43561.2	1433.4	23054.4	36131.8	7018.4	80928.0
2020	167042.6	29214.2	182971.4	9507.8	48874.2	1619.2	24706.2	39823.6	7351.9	85576.2
2025	180059.0	31299.6	195084.6	10725.2	55106.8	1841.7	26451.2	43872.2	7645.2	91920.8
2030	186175.6	36374.4	206509.6	11505.2	62296.0	2021.8	28165.8	48575.0	7944.6	98400.4
World relative prices					(1970 = 1)					
1990	4.691	6.175	21.467	12.157	5.100	5.939	2.248	6.000	18.937	0.596
1995	4.036	6.412	21.756	13.224	4.467	5.917	2.042	5.824	19.760	0.620
2000	4.364	7.211	22.467	14.513	4.867	6.150	2.088	6.032	19.962	0.586
2005	4.218	7.693	22.978	15.399	4.783	6.199	2.105	5.969	20.129	0.587
2010	4.291	7.816	23.622	16.016	4.850	6.313	2.109	5.994	20.188	0.581
2015	4.364	7.904	24.311	16.397	4.883	6.378	2.139	6.032	20.115	0.575
2020	4.400	7.904	25.000	16.630	4.900	6.409	2.109	5.998	19.948	0.577
2025	4.418	7.947	25.622	16.610	4.883	6.402	2.122	5.991	19.685	0.577
2030	4.345	7.982	26.022	16.309	4.850	6.345	2.042	5.913	19.333	0.585

Notes

[1]For example, between January 1990 and May 1991 at least 10 articles and viewpoints in *Energy Policy* have focused on the role of renewables in energy and/or transport policy: Boyle (1990), Grubb (1990a), Grubb (1990b), Hughes (1991), Jackson (1991), Legget (1991), McGowan (1991), de Oliveira (1991), Sorensen (1991a), and Sorense (1991b).

[2]Biomass is any organic material composed primarily of carbohydrates and lignin in addition to small amounts of oils, proteins, and other constituents. Wood, grasses, grains, and waste paper are examples of biomass. This study concentrates on the use of particular grasses as biomass feedstocks.

[3]Sperling (1988) points out that the pollutants emitted during the conversion process for methanol is significant, but .that methanol from biomass produces essentially no net CO_2 emissions in production, distribution, and use activities because roughly as much CO_2 is absorbed by the biomass crops before harvesting as is emitted by combustion of the manufactured fuels.

[4]The BLS is also popularly known as the IIASA model; it was originally developed by (and is still maintained at) the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

[5]One quad is equivalent to 10^{15} Btu's.

[6]In 1982, the United States consumed about 200 million gallons of ethanol from biomass products . (.USDA-DOE, 1983).

[7]Tyson, et al. (1991). Current usage is about 13 quads.

[8]Argentina, Australia, Austria, Brazil, Canada, CMEA, China, EC-9, Egypt, India, Indonesia, Japan, Kenya, Mexico, New Zealand, Nigeria, Pakistan, Thailand, Turkey, and the United States.

[9]The Agricultural Resource Interregional Modelling System (ARIMS) operated at Iowa State University's Center for Agricultural and Rural Development.

[10]See Tyson et al. (1991) for a more complete description.

[11] Results for the U.S. macroeconomy and for world production are incomplete for two reasons. First, the structural effects of reduced petroleum use and imports are not accounted for. Second, biomass production in other countries is not modelled in the BLS.

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