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United States Country Report for IEA Integrated Bioenergy Systems Activity

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United States Country Report for IEA Integrated Bioenergy Systems Activity

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ABSTRACT

In the United States, biomass energy systems are viewed as means to mitigate greenhouse gases, decrease dependence on foreign energy supplies, provide alternative environmentally-friendly crops for agriculture, and enhance rural development opportunities. Successful commercialization depends on energy crop prices being sufficiently low to be competitive with alternative energy feedstocks, yet high enough to provide a profit to farmers comparable to what could be earned in alternative land uses. This paper describes U.S. efforts to model hybrid poplar and switchgrass production costs and supply curves. Estimates of the full economic cost of producing switchgrass bales and hybrid poplar chips in six U.S. regions are presented. Average production costs vary by region and yield, ranging from $US 25 to $62/dry ton for switchgrass bales and $US 30 to $86/dry ton for poplar chips. Biomass prices are generally lower for switchgrass than for hybrid poplar, and are higher in the Lake States and Corn Belt than for other regions. Estimated national biomass supply curves are also presented. Assuming average U.S. yields of 5 dry ton/acre/year, approximately 300 million dry tons of switchgrass could be supplied nationally at farm-gate prices of less than $30/dry ton. Approximately 250 million dry tons of woody crops can be potentially supplied

nationally at farm-gate prices of less than $40/dry ton. This is enough biomass to produce 24 to 33 billion gallons of ethanol at a feedstock price of $0.36 to $0.63/gal (depending on conversion efficiency), or 600 billion kWh at a price of $0.04 to $0.05/kWh.

INTRODUCTION

Being new to the IBS Activity, I do not have a standard country report to present. Instead, I will discuss some of the U.S. efforts to develop and commercialize bioenergy systems. I will describe some of the research projects applicable to the IBS activity that are conducted and/or administered by the Biofuels Feedstock Development Program at Oak Ridge National Laboratory. In particular, I will describe the feedstock product cost and supply modeling activities and the relevance they have for the BEAM model.

In the United States, biomass energy systems are increasingly being viewed as means to mitigate greenhouse gases, decrease dependence on foreign energy supplies, provide alternative environmentally-friendly crops for agriculture, and enhance rural development opportunities. Urban, industrial, and agricultural wastes can be used as biomass energy feedstocks, but supplies at reasonable prices are limited. If biomass energy systems are to provide a significant portion of the energy used in the U.S., production of crops dedicated to energy uses will be required. Since 1978, the U.S. Department of Energy (DOE) has supported biomass energy crop development through the Biofuels Feedstock Development Program (BFDP) at Oak Ridge National Laboratory (ORNL). The BFDP is developing herbaceous and short rotation woody crops that can be used to produce liquid fuels, power, and chemicals.

The BFDP is a multi-disciplinary program that conducts biomass research and administers DOE funded feedstock research. The goal of the program is to develop and demonstrate environmentally acceptable crops and cropping systems for producing large quantities of low-cost, high-quality biomass feedstocks. It coordinates closely with DOE's programs to develop efficient technologies to convert biomass feedstocks to energy, administered by the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

The BFDP works closely with other public and private sector agents. At least 30 universities, 5 U.S. Department of Agriculture (USDA) research units, and 4 private industries have been long-term (5 years or more) participants in BFDP research. Many BFDP projects receive significant cost-sharing from other public and private sources.

The BFDP has screened more than 125 tree and non-woody species and selected a limited number of model species for development as energy crops. The program supports studies in six areas:

Model Wood Energy Species
Model Herbaceous Energy Species
Environmental Research
Systems Integration and Analysis
Scale-Up, Feasibility, and Demonstration
Information Management

The BFDP manages the Biofuels Information Network (BIN) which provides electronic versions of information created by DOE and its support contractors at ORNL and NREL. The BIN currently contains the full text of *Energy Crops Forum*, the DOE reports *Biofuels at the Crossroads* and *Biofuels: A Win-Win Strategy-Stabilizing Global Climate Change While Achieving a Sustainable Energy Future*, several technical reports, conference announcements, and the addresses and phone numbers of the BFDP management team. In the future, articles, white papers, fact sheets and a searchable bibliography will be available. The BIN can be accessed at http://www.esd.ornl.gov/BFDP/BFDPMOSAIC/binmenu.html.

BFDP ACTIVITIES APPLICABLE TO INTEGRATED BIOENERGY SYSTEMS

Several projects conducted and/or administered by BFDP personnel have relevance to the Integrated Bioenergy Systems Activity. BFDP personnel have developed models to estimate the cost of producing a model short rotation woody energy crop (hybrid poplar) and model herbaceous energy crop (switchgrass) in several regions of the United States. Efforts are ongoing to estimate regional and national biomass crop supply curves. GIS-based approaches are being used to estimate supply curves at a local level. Economic modeling is used to determine changes in land use. The economic models are then linked with environmental models to determine the impacts of changing land use on environmental parameters such as erosion and chemical runoff. BFDP personnel are collaborating with NREL personnel to combine ORNL's feedstock supply analysis with NREL's techno-economic analysis to estimate the cost of producing ethanol from woody and herbaceous energy crops. BFDP personnel have also participated in a multi-agency working group (USDA, DOE, Environmental Protection Agency, Office of Science and Technology Policy, Princeton University, Texas A&M University) to estimate the cost of producing electricity from biomass crops as a means to mitigate greenhouse gases.

The BFDP personnel experience with modeling feedstock supply and with linking these models with conversion technology models will be useful in IBS efforts to integrate additional feedstocks into the BEAM model. Because of the applicability to IBS activities, the biomass feedstock production cost and supply modelling activities will be described in greater detail.

BIOMASS PRODUCTION COST MODELS

The costs of producing dedicated energy crops have been estimated for six regions of the United States--the Lake States (MI, MN, WI); the Corn Belt (IA, IL, IN, MO, OH); Appalachia (KY, NC, TN, VA, WV); the Southeast (AL, GA, SC); the North Plains (KS, NE, ND, SD); and the South Plains (OK, TX) (Walsh, 1994a; Walsh, 1994b). Energy crops can be produced in other regions of the U.S.; these regions correspond to the production regions for major U.S. agricultural crops. Switchgrass and hybrid poplars have been chosen as representative herbaceous and short rotation woody crops because of their high yield potential and wide geographical distribution, and because the production methods used to produce them are typical of those that will be used to produce many other potential energy crops resulting in similar production costs. Other energy crops can be produced, and may be preferable in some areas.

Switchgrass and hybrid poplars are not currently produced as dedicated energy crops; historical production cost data is lacking. The production costs must be estimated using reasonable assumptions of the management practices that will be used to produce these crops. The production cost estimations utilize an engineering approach. Using engineering data, the hours required for a machine to complete an operation can be calculated. Combined with the per hour costs of using the machine, the total cost of the operation can be estimated.

A full economic cost accounting approach is used. This approach assumes that all resources used in production have value, regardless of ownership status. Thus the estimated production costs include not only the variable out-of-pocket cash expenses (e.g., seeds, chemicals, fertilizer, fuel, repairs, and hired labor), but fixed cash costs (e.g., overhead, taxes, interest payments), and the costs of owned resources (e.g., the producer's own labor, equipment depreciation, land values, the opportunity cost of capital investments) as well. This approach is conservative, and leads to higher estimated costs than if only variable cash expenses are used. The approach is most useful for policy analysis, however, even for farmers who base year-to-year planting decisions on variable costs, a full cost accounting is useful in determining long term survival and expansion potential and to evaluate quality of life issues.

The estimates assume farmers own all of the equipment needed to produce energy crops except those needed to harvest hybrid poplars. Machinery and equipment complements typical of commercial-scale farm operations in each region are used; size varies by region. Input prices are in 1993 U.S. dollars. Costs are estimated for on-farm production only; no transportation costs are included. Round-trip transportation costs are expected to be about $US 10.00 to $12.00 per dry ton ($11.00-13.20/Mg) for hauling distances of less than 75 miles (120 km). The approach used is, to the greatest extent possible, consistent with that used by the U.S. Department of Agriculture, Economic Research Service to estimate the costs of producing major field crops (USDA, 1994). Thus the production cost estimates are consistent with production cost estimates of major field crops and are readily comparable.

Supply curves are estimated for four regions in the United States--The North Central Region (IA, IL, IN, KY, MI, MN, MO, KS, NE, ND, SD, WI); the Northeast Region (CN, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, VT, WV); the Southeast Region (FL, GA, NC, SC, VA); and the South Central Region (AK, AL, LA, MS, OK, TN, TX). A partial equilibrium approach is used to estimate the curves, and should be interpreted with caution (Graham, 1995). This approach assumes that the prices of other goods (i.e., conventional crops) remain fixed as biomass production increases; conventional crop prices do not increase as acreage is removed from their production to produce biomass energy crops. Thus, the accuracy of the supply analysis extends only to the acreage that is currently not used to produce conventional crops. From the middle of the Plains States eastward, approximately 35 to 50 million acres are potentially available for biomass production without significantly affecting conventional crop prices (i.e., 17 million Conservation Reserve Program acres (CRP), 10-20 million Acreage Reduction Program acres (ARP), and 5-10 million pasture acres with high conversion potential) and depending on changes in agricultural programs that may occur in the 1995 Farm Bill (Walsh, 1995). Beyond this range, the partial equilibrium approach significantly underestimates the price of biomass crops.[1]

The supply curve estimates are based on the premise that farmers will produce biomass crops if the expected profit of these crops exceeds the profit that can be earned from the production of conventional crops on the same land. Risk considerations and the perceived value of the environmental benefits are not included in the analysis. A distribution of CRP rental rates (12th sign-up) by land capability class in each region is used as a proxy for the profitability of conventional crops. Biomass crop yields by land capability class in each region are based on expert opinion and field trial and research plot data. Biomass production costs are those estimated above. The price needed to ensure biomass profits comparable to conventional crop prices can be estimated by solving for BP in equation 1.

National supply curve estimates using a general equilibrium model (FASOM) and the same biomass production costs and yields parallels the partial equilibrium approach for the first 40 million acres of production and then begins to deviate sharply. This suggests that the partial equilibrium approach can reasonably approximate national biomass quantities and prices from 0 to 40 million acres of production, but is unreliable beyond this range (McCarl, 1994).

Site preparation is assumed to consist of moldboard plowing and disking. In some areas, no-till or conservation-till practices will be employed; estimated cost differences will not be large. Lime, phosphorous, and potassium are broadcast applied as needed prior to planting. Quantities used for estimation are those typically used in the region for the production of other crops. Herbicides to control competing grasses and broadleafs are applied to aid establishment. Weed control is assumed to be necessary in years one and two of production for switchgrass hybrid poplars and consists of both chemical and mechanical weed control. The analysis assumes annual applications of nitrogen for switchgrass and biennial nitrogen applications for hybrid poplar.

Switchgrass stands are assumed to remain in production for 10 years before replanting. Harvesting occurs in years 2-10 and consists of mowing, raking and round baling. Hybrid poplars are assumed to be planted at a 6' x 8' (1.8 x 2.4 m) spacing (910 trees/acre, 2248 trees/ha) and are harvested in the seventh year of production. It is assumed that hybrid poplar harvest is by custom operation, and given the lack of data available for custom harvest rates for short rotation, intensely managed trees, it was necessary to estimate what these costs might be. Hybrid poplar harvest is assumed to consist of a felling-bunching operation, skidding to a landing site, and chipping. Other harvesting options have been proposed (e.g., whole-tree harvesting) which could potentially result in considerably lower harvesting costs, but these alternatives are not currently operational. Production cost estimates are adjusted for expected yields. The per dry ton net present value cost of producing switchgrass bales and hybrid poplar chips is calculated using a 6.5 percent discount rate.

Production costs vary by region due to differences in labor rates, machinery complement, variety planted, level of chemical and fertilizer inputs used, fixed costs, expected yields, and land rental rates with yields and rental rates being the most significant factors. Tables 1 and 2 summarize the regional costs of producing switchgrass bales and hybrid poplar chips respectively for selected yields. Example detailed switchgrass and hybrid poplar budgets are presented in tables 3 and 4. Switchgrass bale production costs range from approximately $US 25/dry ton ($28/Mg) in the Southeast to nearly $US 62/dry ton ($68/Mg) in the Lake

$$R_{ijk} = BP_{ijk} * BY_{ijk} - BPC_{ilk} \qquad (1)$$

where

R = the profitability of conventional crop i for land capability class j in region k

BP = price of biomass i for land capability class j in region k

BY = yield of biomass i for land capability class j in region k

BPC = production cost of biomass i for subregion l in region k

Multiplying the estimated breakeven price (BP) by the corresponding acres and yields (BY) provides an estimate of the total number of tons that can be produced nationally at price BP. Estimated national supply curves for biomass (Figures 3 and 4) suggest that for an average national yield of 5 dry tons/acre/yr (11 Mg/ha/yr), approximately 300 million tons (272 million Mg) of switchgrass could be provided at farm-gate prices of less than $US 30 per dry ton ($33/dry MG) ($US 40/dry ton delivered with a $US 10/dry ton transportation costs) or approximately 250 million dry tons (227 million dry Mg) of hybrid poplar could be supplied at farm-gate prices of less than $US 40 per dry ton ($44/dry Mg) ($50/dry ton with transportation costs of $10/dry ton) (Graham, 1995).

Biomass quantities at this level and price are sufficient to produce 24 to 33 billion gallons (91 to 125 liters) of ethanol at a feedstock price of $US 0.36 to $0.63/gal ($0.10 to $0.17/liter) depending on conversion efficiency of 80 gal/ton (334 liters/Mg) and 110 gal/ton (459 liters/Mg) respectively. If used for electricity generation, approximately 600 billion kWh could be produced at a price of $US 0.04 to $0.05/kWh (Graham, 1995). Currently the U.S. produces approximately 1 billion gallons (3.8 billion liters) of ethanol for use in fuels utilizing corn as the primary feedstock. The current net corn prices (credits given for co-products) for ethanol production are approximately $US 0.44/gal ($0.12/liter) and $0.53/gal ($0.14) for wet and dry milling operations (Hohmann, 1993). Approximately 5 percent of U.S. electricity production could be supplied at prices within the range of electricity production costs in the U.S., although for many regions of the country, biomass electricity costs are higher.

A delivered price of $US 40/dry ton ($44/dry Mg) for switchgrass bales is approximately $2.07/MBTU. A $US 50/dry ton ($55/dry Mg) delivered price for hybrid poplar chips is about $US 3.03/MBTU ($2.87/MJ). Delivered prices for coal are approximately $US 1.45/MBTU ($1.40/MJ) and $US 1.65/MBTU ($1.57/MJ) for natural gas. Biomass prices are somewhat higher than fossil fuels at the current time. However, improvements in yields and harvesting technologies can lower the price of biomass, and a reflection of externalities (such as health and environmental effects) in the price of fossil fuels would help to level the playing field.

SUMMARY

Personnel at BFDP have developed models that can calculate hybrid poplar and switchgrass production costs for six regions in the United States. Aggregate (national and regional) supply models have also been developed, and efforts are underway to develop local supply curves. These models can be readily adapted for inclusion in BEAM.

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TABLE 1: ESTIMATED COST OF PRODUCING SWITCHGRASS BALES BY REGIONS FOR SELECTED YIELDS (DOLLARS/DRY TON)

	3 DT/AC/YR	4 DT/AC/YR	5 DT/AC/YR	6 DT/AC/YR	7 DT/AC/YR	8 DT/AC/YR
LAKE STATES	62	48	40			
CORN BELT		53	48	43		
APPALACHIA	54	43	36			
SOUTH EAST				28	25	30
SOUTH PLAINS			29	26	26	

TABLE 2: ESTIMATED COST OF PRODUCING HYBRID POPLAR CHIPS BY REGION FOR SELECTED YIELDS (DOLLARS/DRY TON)

	3 DT/AC/YR	5 DT/AC/YR	7 DT/AC/YR
LAKE STATES	75	49	38
CORN BELT	86	55	40
SOUTHEAST	63	41	30

FIGURE 1: IMPACT OF ASSUMPTION CHANGES ON THE COST OF PRODUCING SWITCHGRASS

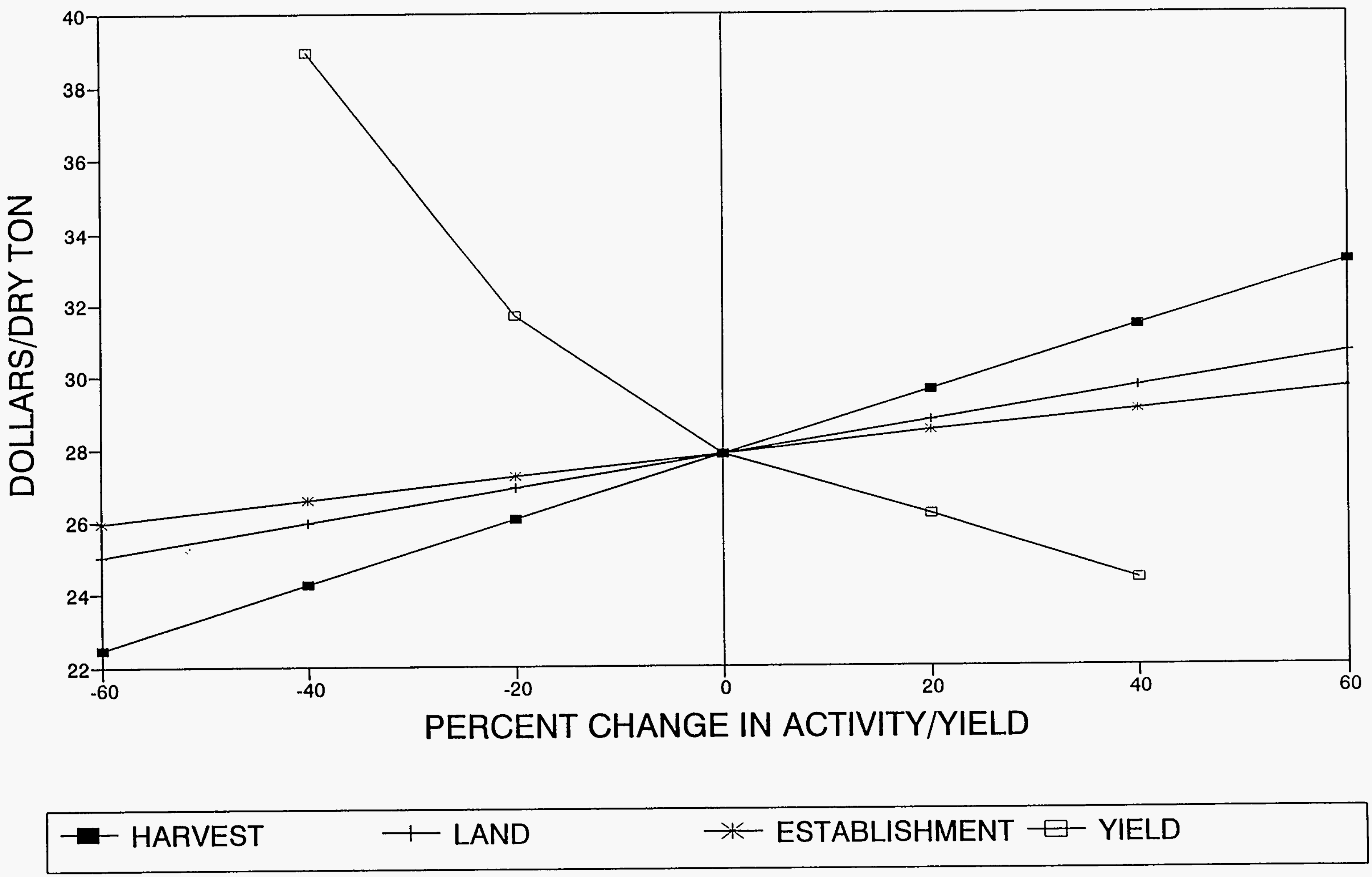


FIGURE 2: IMPACT OF ASSUMPTION CHANGES ON THE COST OF PRODUCING SRWC

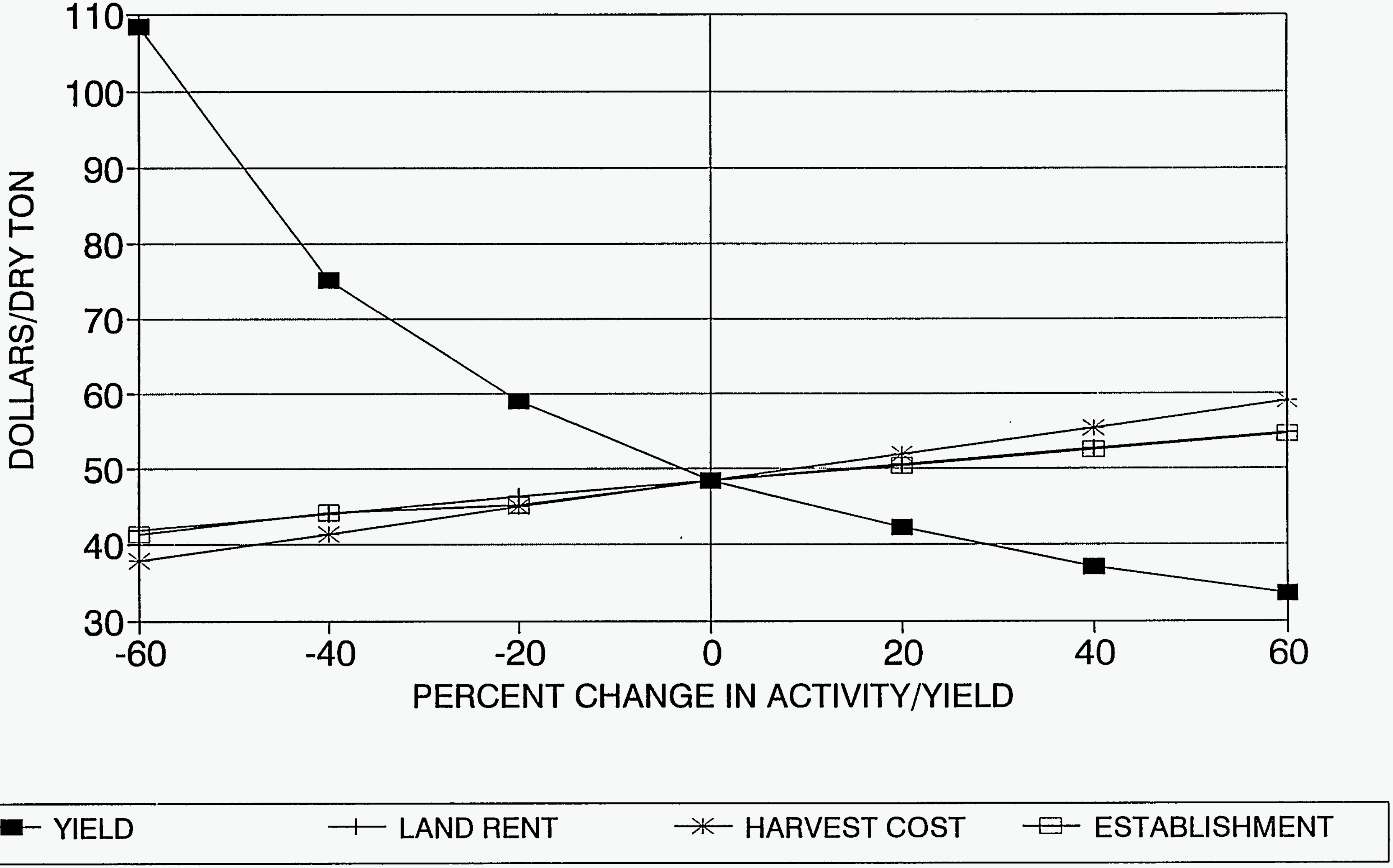


FIGURE 3: U.S. SRWC SUPPLY

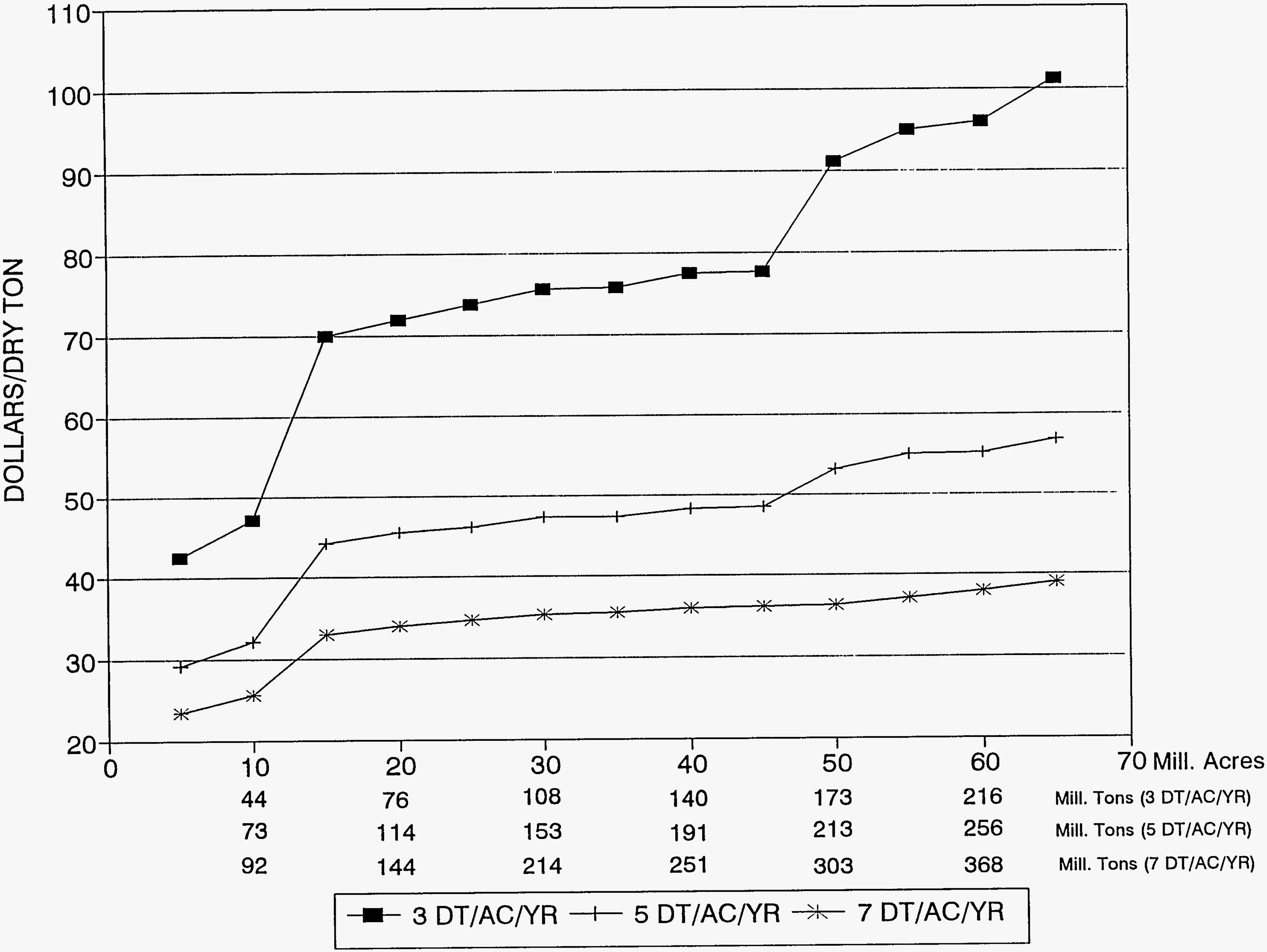
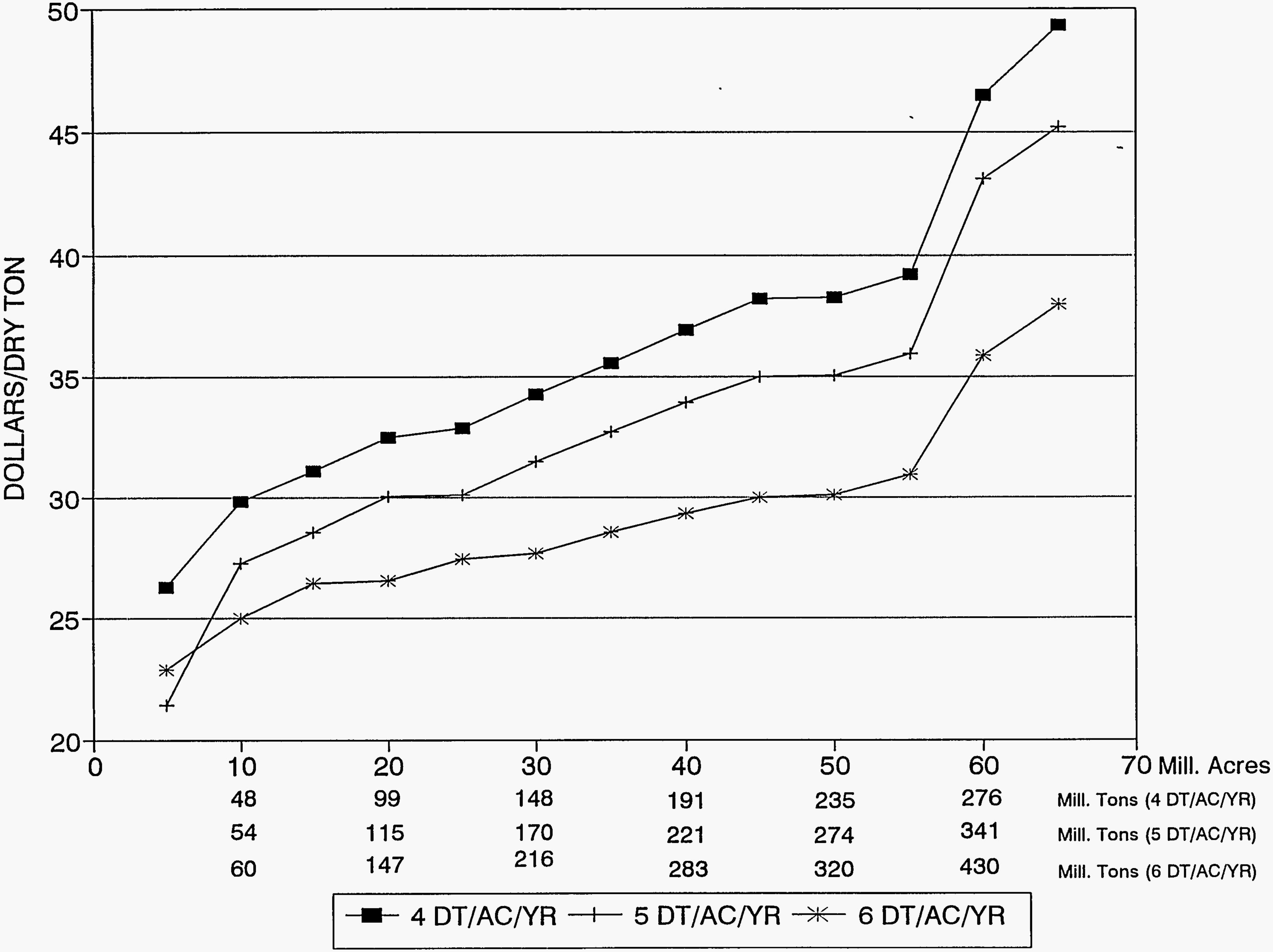


FIGURE 4: U.S. SWITCHGRASS SUPPLY



ABSTRACT

In the United States, biomass energy systems are viewed as means to mitigate greenhouse gases, decrease dependence on foreign energy supplies, provide alternative environmentally-friendly crops for agriculture, and enhance rural development opportunities. Successful commercialization depends on energy crop prices being sufficiently low to be competitive with alternative energy feedstocks, yet high enough to provide a profit to farmers comparable to what could be earned in alternative land uses. This paper describes U.S. efforts to model hybrid poplar and switchgrass production costs and supply curves. Estimates of the full economic cost of producing switchgrass bales and hybrid poplar chips in six U.S. regions are presented. Average production costs vary by region and yield, ranging from $US 25 to $62/dry ton for switchgrass bales and $US 30 to $86/dry ton for poplar chips. Biomass prices are generally lower for switchgrass than for hybrid poplar, and are higher in the Lake States and Corn Belt than for other regions. Estimated national biomass supply curves are also presented. Assuming average U.S. yields of 5 dry ton/acre/year, approximately 300 million dry tons of switchgrass could be supplied nationally at farm-gate prices of less than $30/dry ton. Approximately 250 million dry tons of woody crops can be potentially supplied nationally at farm-gate prices of less than $40/dry ton. This is enough biomass to produce 24 to 33 billion gallons of ethanol at a feedstock price of $0.36 to $0.63/gal (depending on conversion efficiency), or 600 billion kWh at a price of $0.04 to $0.05/kWh.