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Modeling price-driven interactions between wood bioenergy and global wood product markets

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ABSTRACT

Higher and more volatile liquid fossil fuel prices have had profound effects on international energy and wood product markets. Understanding this evolving economic and technological landscape requires economic models that capture the interconnections between energy markets and wood product markets, and can be used to forecast the impact of alternative policy and market incentives. The need for such an analytic framework is underscored by the consensus that efficiently produced wood bioenergy could provide many climate benefits compared to fossil-fuel intensive substitutes.

A model is presented for analysis of how increased use of wood bioenergy, in the forms of fuelwood, cellulosic ethanol from woody biomass, and electricity produced from wood, might interact with global markets for wood products; liquid, solid, and gaseous fuels; and electricity produced from other sources. It links U.S. energy markets with wood product markets and endogenizes the demand for wood bioenergy with price-driven market clearing mechanisms. Projections made with the model point to a substantial increase in demand for woody cellulosic ethanol in the U.S. for the next 30 years if oil prices remain high.

1. Introduction

Production of renewable energy has been increasing rapidly due to high fossil fuel prices, increasing global energy demand, advances in renewable energy technologies, and a variety of government policies. Public support for these policies is driven by evidence that utilizing renewable energy is an efficient way to lower greenhouse gas (GHG) emissions and mitigate climate change. Bioenergy is the largest renewable energy component (~10% of the total supply) [1]. Gurgel et al. [2] projected that under a global effort to mitigate GHG emissions, biomass production in 2050 could reach levels between 122 and 135 EJ in 2050 and 319 and 368 EJ in 2100 – a dramatic increase from the current 35 to 55 EJ. The International Energy Agency (IEA) predicted that, conservatively, bioenergy production could increase even more – to 200–400 EJ by 2050 [3]. These projected increases in bioenergy production reflect a general consensus that global petroleum production will peak and decline, and that many countries will also implement policies to reduce the dependence on fossil fuels for electricity generation. A better understanding of how changes in the global market for renewable energy might draw woody biomass from intensively managed forests, extensively managed forests, and short rotation plantations is critical for reliable economic forecasting, investment decisions, and policy formation in both the

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forestry and energy sectors. This paper describes modifications to a widely used global forest production and trade model to capture the potentially different price responses of the three main types of wood bioenergy (heat, electricity, and liquid fuels) in a global content.

Wood bioenergy can be produced from a variety of biomass feedstocks such as forest biomass and wood waste; agricultural biomass and residue; and dedicated energy crops [4]. These biomass feedstocks can be used to directly produce heat or electricity, or be processed into transportable fuels. Some examples of commercially available technologies to utilize biomass include small- and large-scale boilers, domestic pellet-based heating systems, and ethanol production from sugar and starch. Various lignocellulose-based biofuels production systems are moving toward commercial production [1].

The European Union is the largest wood energy market in the world, and its production and consumption potential continues to grow. Fig. 1 shows wood energy use by sector in the U.S. relative to twenty-five European countries. Increases in EU's wood energy demand are driven by wood pellet demand for co-firing, combined heat-and-power (CHP), and residential and district heating [6]. Wood energy is continuing to decline in the U.S. as a share of renewable energy consumption, falling from 35% in 2000 to 22% in 2012 [7]. The wood-industry and residential heating sectors are the two major consumers of wood energy in the U.S., accounting for 64% and 24% of total consumption respectively. Because of the natural gas development in recent decade in North America, wood pellets for heating have lost market share where natural gas is available and inexpensive. Wood pellet manufacturing and exports in the U.S. and Canada are mainly responding to increasing demands in the EU.

For the U.S., Annual Energy Outlook 2013 forecasts an increase of more than 70% in biomass energy consumption by 2040, compared to projection for 2013 [7]. Residential and commercial sector consumption is projected to remain flat, with the increase evenly split between the electric power sector and the industrial uses. The electric power generated by wood and other biomass is projected to increase 7% annually. Consumption of ethanol from cellulosic sources, on the other hand, is projected to increase from zero in 2012 to 21.1 PJ in 2014, and remain flat thereafter.

Understanding wood bioenergy uses and flows among nations is a critical component for assessing global forest sustainability. To analyze both market-driven and policy-driven expansions in wood bioenergy consumption in the future, we modified a partial equilibrium model of the forest sector to endogenize wood bioenergy demand, expanding the product categorization to separate: (1) fuelwood; (2) cellulosic ethanol from woody biomass; and (3) electricity and industrial heat. These modifications provide a flexible analytic tool for evaluation of the interactions between markets for wood bioenergy and other wood products, and for electricity, liquid, solid, and gaseous fuels.

2. Methods

2.1. *Model structure and modification*

The Global Forest Products Model (GFPM) models the global production, consumption and trade in 14 principal categories of forest products for 180 individual countries. The model represents, for each country, supplies of wood and non-wood fiber raw materials, production of intermediate wood products, and production and consumption of final wood product commodities. All product demands, except fuelwood (or wood bioenergy) demand, are represented by price-responsive and GDP-driven demand functions in each country, while fiber raw material supplies are represented by price-responsive supply functions. Fuelwood demand in each country is represented by a price-responsive demand function with exogenously specified long-run demand shifters and scenario assumptions. Traditional higher-value forest products are modeled with raw material input–output (I/O) coefficients and unit manufacturing costs, and transportation activities with unit transport costs [5,8].

The U.S. Forest Products Module (USFPM) [8] is a special version of the GFPM with an expanded U.S. specification of regional markets and product categories. The USFPM was developed to support the U.S. Forest Service's nationwide

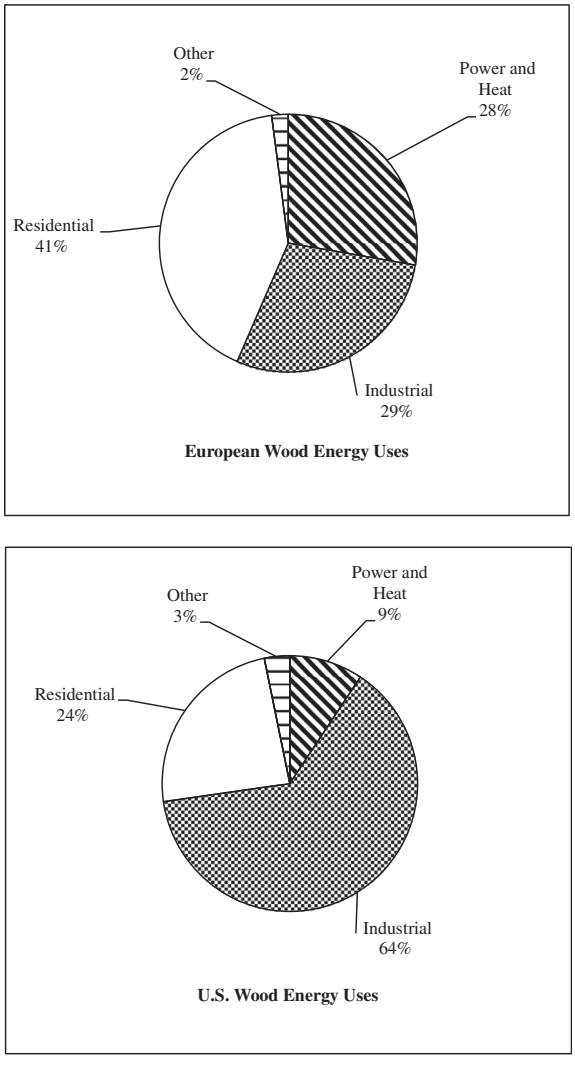

Fig. 1 – European and U.S. wood energy uses per sector. European (excluding the Russian Federation) total woody biomass supply: 752 dam^3; U.S. total woody biomass supply: 527 dam^3. Source: UNECE/FAO Joint Wood Energy Enquiry, 2011 [34].