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Dynamic analysis of policy drivers for bioenergy commodity markets

Robert F. Jeffers *, Jacob J. Jacobson [1], Erin M. Searcy [2]

Idaho National Laboratory, Post: PO Box 1625, Environmental Engineering & Technology, 2525 N Fremont Ave., MS: 3710, Idaho Falls, ID 83415, USA

HIGHLIGHTS

- ► We model a United States bioenergy feedstock commodity market.
- ► Three buyers compete for biomass: biopower, biofuels, and foreign exports.
- ► The presented methodology improves on dynamic economic equilibrium theory.
- ► With current policy incentives and ignoring exports, biofuels dominates the market.
- ► Overseas biomass demand could dominate unless a CO_2-limiting policy is enacted.

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ABSTRACT

Biomass is increasingly being considered as a feedstock to provide a clean and renewable source of energy in the form of both liquid fuels and electric power. In the United States, the biofuels and biopower industries are regulated by different policies and have different drivers, which impact the maximum price the industries are willing to pay for biomass. This article describes a dynamic computer simulation model that analyzes future behavior of bioenergy feedstock markets given policy and technical options. The model simulates the long-term dynamics of these markets by treating advanced biomass feedstocks as a commodity and projecting the total demand of each industry, as well as the market price over time. The model is used for an analysis of the United States bioenergy feedstock market that projects supply, demand, and market price given three independent buyers: domestic biopower, domestic biofuels, and foreign exports. With base-case assumptions, the biofuels industry is able to dominate the market and meet the federal Renewable Fuel Standard (RFS) targets for advanced biofuels. Further analyses suggest that United States bioenergy studies should include estimates of export demand in their projections, and that GHG-limiting policy would partially shield both industries from export dominance.

1. Introduction

The use of biomass as a feedstock for energy production is one option to provide a clean, renewable, and domestic source of energy. Although biomass is a renewable resource, the amount that can be grown sustainably and accessed economically is limited (US Department of Energy (DOE), 2011a). In the United States (US), growth in the use of biomass feedstocks for energy production is increasingly being driven by governmental policies such as Renewable Fuels Standard (RFS) for biofuels production and Renewable Portfolio Standards (RPS) for biopower production (Sorda et al., 2010; US Department of Energy (DOE), 2010). However, the future size and strength of the bioenergy industry in the US is uncertain in the face of high values for biomass overseas that may drive up domestic prices for processed bioenergy feedstocks. Additionally, the potential for greenhouse gas (GHG)-limiting legislation creates uncertainty for investors in bioenergy and could disproportionately change the value of biomass for biopower compared to biofuel. The US Department of Energy (DOE) is investigating the utility of a commoditized uniform format for bioenergy feedstocks, which would expand access to many biomass industries and biomass resources, help minimize market volatility, and reduce risk to both biorefineries

Abbreviations: DOE, United States Department of Energy; EERE, DOE Office of Energy Efficiency and Renewable Energy; EISA, Energy Independence and Security Act of 2007; EPA, Environmental Protection Agency; EU, European Union; IEA, International Energy Agency; Gas, Petroleum-based gasoline; GHG, Greenhouse Gas; MYPP, OBP Multi-Year Program Plan; OBP, Office of Biomass Program within DOE, EERE; REC, Renewable Energy Certificate; RFS, Renewable Fuel Standard; RIN, Renewable Identification Number; RPS, Renewable Portfolio Standard; US, United States of America

* Corresponding author. Tel.: +1 208 526 9611; fax: +1 208 526 5647.
E-mail addresses: Robert.Jeffers@inl.gov (R.F. Jeffers), Jacob.Jacobson@inl.gov (J.J. Jacobson), Erin.Searcy@inl.gov (E.M. Searcy).
[1] Tel.: +1 208 526 3071.
[2] Tel.: +1 208 526 0819.

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Nomenclature

Units of measure

$	US dollars
Bgal	Billion US gallon
gal	US gallon
GGE	Gallons of gasoline equivalent
Gl	Gigalitre, 1E9 litre
GW	Gigawatts of electric power
l	Litre, 0.001 m^3
MW h	Megawatt hour of electrical energy
Mton	Million US short ton
Mt	Million metric tonne
t	Metric tonne
ton	US short ton

and biomass producers (Hess et al., 2009; Searcy and Hess, 2010). While the uniform format removes some risk and limits to growth of bioenergy, it may enhance direct competition for bioenergy feedstocks among biopower, biofuels, and exporters. Therefore, as government and industry focus on the use of biomass as a commoditized feedstock for clean and renewable energy production, a need arises for techno-economic analysis regarding the effect of policies and strategies on the sustainability of multiple bioenergy industry sectors.

This study analyzes the emerging bioenergy industry by investigating patterns in the behavior of bioenergy feedstock markets given a range of technical and policy options. The article begins with a review of bioenergy technologies and policies that are creating a commodity market for bioenergy feedstocks. The core of the article presents the Bioenergy Market Model, which simulates the primary causes of growth in bioenergy feedstock markets and furthermore presents simulated scenarios that describe the effect of technologies and policies on three bioenergy industries: biopower, biofuels, and exports. This model also presents a graphical method of analyzing the dynamic allocation of commodities to multiple buyers given a revenue-maximizing supplier and allowing for supply or demand-limiting conditions. This is a new approach to dynamic market allocation that attempts to quantify instantaneous demand vs. price curves for potential buyers. Scenarios are presented that show a wide range of behaviors for the bioenergy feedstock market based on assumptions about the implementation of current bioenergy policy, the strength of export markets, the bioenergy technologies used, and the effects of greenhouse gas (GHG)-limiting legislation.

2. Technology description

2.1. Biofuels technology

To be economically viable, biofuels will need to be cost-competitive (after tax and subsidy) with conventional fossil fuel based transportation fuels such as gasoline. Although DOE's Office of Biomass Program is working with industry to develop, build, and operate integrated biorefineries at various scales (e.g., pilot, demonstration, and commercial), it is assumed in the mean time as these integrated biorefineries are designed and tested that conventional biorefineries can fill the gap. For the purpose of this study, we assume the economics of refinery production only hinge on liquid fuel cost targets that are based on competitiveness with conventional transportation fuels. From discussion, a nominal value of the cost target for biofuel at the output of the biorefinery is 0.79 $\$\,l^{-1}$ (3 $\$\,gal^{-1}$).

There are a variety of options for converting biomass into biofuels, generally divided into biochemical (biological-based) and thermochemical (heat-based) conversion processes. Although there are specific technologies within each of these general categories, biochemical conversion technologies, such as enzymatic hydrolysis, desire feedstocks with a high carbohydrate content and will be wet at the time of conversion (for example, Aden, 2008). Thermochemical conversion processes, such as gasification and pyrolysis, generally require a dry feedstock that is low in ash content and has a small, consistent particle size (for example, Phillips et al., 2007; Dutta et al., 2011). Because of these generalizations, herbaceous feedstocks that are naturally higher in ash and carbohydrates are generally allotted to biochemical conversion, while woody feedstocks with their lower ash content are directed to thermochemical conversion. Although yields for various conversion technologies vary greatly, we applied yields and costs from recent DOE design reports on biofuels production (Kabir Kazi et al., 2010; Dutta et al., 2011; Phillips et al., 2007) to simplify a model representing multiple disparate conversion processes down to conversion efficiency ($l\,t^{-1}$), which is the amount of biofuel produced per ton of biomass used, and conversion cost ($\$\,l^{-1}$), which is assumed to be a fixed cost over the annual timeframes considered herein.

2.2. Biopower technology

Biomass combustion to generate electricity has existed in the United States since the inception of the power grid. Historically, woody biomass, such as residues from timber harvesting, sawmilling, and pulp and paper, has been a feedstock to co-located, direct-fired boilers for electricity generation and/or heat. Agricultural residue, primarily from wheat and corn harvests, has also contributed to biopower production. These practices have grown the biopower industry into the third highest generator of renewable electricity in the nation next to hydropower and wind power, providing 12% of US renewable generation capacity in 2010 (Energy Information Administration (EIA), 2011a). Biopower is increasingly being targeted as an option to reduce GHG emissions from the electrical power industry. However, the existing paradigm of small, co-located plants is not economically scalable to reach large emission cuts. The biopower industry is therefore exploring the option of co-firing energy-dense biomass in existing coal plants at mixtures of up to 20% biomass to decrease emissions, meet renewable energy targets, and continue to support energy security (US Department of Energy (DOE), 2010). To be economically viable, this option must be cost-competitive with standard coal plants, and must also compete against other renewable technologies that may replace coal in the future.

This study considers co-firing biomass with coal as a domestic option for reducing GHG emissions from the electric power industry. Multiple technologies exist for modifying existing coal plants to co-fire biomass. Conventional woody feedstocks, such as debarked, chipped pine are readily available at many locations but may require significant modifications to the plant, including the potential for de-rating its output capacity. However, if the biomass is dried and energy density increased via a process such as torrefaction, a potentially low-cost heating method that reduces the biomass to near-zero moisture content and increases energy density, it behaves much more like coal and minimal modifications are necessary to existing coal plants assuming the