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Estimating the variable cost for high-volume and long-haul transportation of densified biomass and biofuel

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ABSTRACT

This article analyzes rail transportation costs of products that have similar physical properties as densified biomass and biofuel. The results of this cost analysis are useful to understand the relationship and quantify the impact of a number of factors on rail transportation costs of denisfied biomass and biofuel. These results will be beneficial and help evaluate the economic feasibility of high-volume and long-haul transportation of biomass and biofuel. High-volume and long-haul rail transportation of biomass is a viable transportation option for biofuel plants, and for coal plants which consider biomass co-firing. Using rail optimizes costs, and optimizes greenhouse gas (GHG) emissions due to transportation. Increasing bioenergy production would consequently result in lower GHG emissions due to displacing fossil fuels. To estimate rail transportation costs we use the carload waybill data, provided by Department of Transportation's Surface Transportation Board for products such as grain and liquid type commodities for 2009 and 2011. We used regression analysis to quantify the relationship between variable transportation unit cost ($/ton) and car type, shipment size, rail movement type, commodity type, etc. The results indicate that: (a) transportation costs for liquid is $2.26/ton–$5.45/ton higher than grain type commodity; (b) transportation costs in 2011 were $1.68/ton–$5.59/ton higher than 2009; (c) transportation costs for single car shipments are $3.6/ton–$6.68/ton higher than transportation costs for multiple car shipments of grains; (d) transportation costs for multiple car shipments are $8.9/ton and $17.15/ton higher than transportation costs for unit train shipments of grains.

Introduction

Fossil fuels, such as oil, coal and natural gas currently represent the prime source of GHG emissions in the world. The increasing energy demand, coupled with increasing concerns over global warming, have resulted in an increased interest in a variety of renewable energy resources (RES) such as biomass, solar, and wind. United States Department of Energy (2006) has identified biofuels as one of the energy sources in the USA that will reduce nation's dependency on fossil fuels, thereby having a positive impact on the environment, and economy. A variety of biomass feedstocks are presently used to produce biofuel and electricity. According to EIA, biomass contributes nearly 3.9 quadrillion British thermal units (BTU) and accounts for more than 4% of total US primary energy consumption (EIA, 2010a). Over the last 30 years, the share of biomass

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in the total primary energy consumption has averaged less than 3.5% (EIA, 2010a). The US federal government passed the Energy Independence and Security Act (2007) to increase the share of biomass in the total energy production. The Act specifically calls for US production of liquid transportation biofuels to increase to more than 136 billion liters annually by 2022, with approximately 76 billion liters coming from non-cornstarch feedstock. Additionally, a number of policies and incentives at the Federal and State level are expected to increase generation of electricity from renewable resources, such as using biomass for co-firing. A recent study by Roni et al. (in press) shows that a 10% biomass co-firing in coal fired power plant would result in 81–96 Million Ton reductions in CO_2 emissions. Policies at the Federal level – such as, the renewable energy production tax credit (PTC) – provide an income tax credit of 2.2 cents/kilowatt-hour. The Annual Energy Outlook (EIA, 2013) projects that electricity production from biomass will increase from 37.26 billion kilowatt-hours in 2011 to 131.89 billion kilowatt-hours in 2040 (see Fig. 1).

It is expected that bioenergy production will increase in the near future due to the policies and incentives listed above. Fig. 1a. shows that ethanol production has continuously increased in the recent years mainly due to the RFS requirements. Fig. 1b. presents the current amount of electricity generated through biomass co-firing, as well as, the expected increase of electricity generation in the next few years.

Investors in second-generation biofuels will face decisions related to biorefinery locations and supply chain design. These decisions are not easy since they are subject to a number of factors, such as proximity to biomass resources, transportation costs, and railway accessibility. In the past, corn-based biofuel plants were typically located within 50 miles radius of their supply in order to minimize in-bound transportation costs (Aden et al., 2002). Consequently, the size of these plants was limited by the amount of biomass within this radius. Physical characteristics of lingocellulosic biomass and geographical factors represent a serious limitation to bioenergy supply-chain dynamics. Identifying the factors that impact rail transportation costs of biomass, and quantifying the impact of these factors on unit transportation costs is important because this knowledge allows biorefineries and coal plants to plan ahead and better design and manage their supply chains.

Biomass, in the form of agricultural and forest waste, has low density and poor flowability properties, and thus, it is bulky, heterogeneous, and unstable. In addition, biomass suppliers are typically small or medium sized farms, which are widely dispersed geographically. For these reasons, processes such as loading, unloading and transportation of biomass are challenging and expensive. Recent reports published by the Idaho National Laboratory (INL) propose a commodity-based, advanced biomass supply chain design concept to support the large-scale production of biofuels (Hess et al., 2009; Searcy and Hess, 2010). This system relies on densifying biomass at local preprocessing facilities before delivering to a biorefinery and before long distance transportation. Densified biomass refers to biomass that has undergone preprocessing to increase the bulk density of the material, such as pelletization, briquetting. When we use the term densified biomass in this paper, we refer to pellets of size less than 3/16 in. which follows the target size specifications for the biochemical conversion process design under development by National Renewable Energy Laboratory (Tumuluru et al., 2010, 2011). Densifying transforms biomass into a stable, dense, and flowable commodity. This conversion makes the feedstock easier to load and unload on

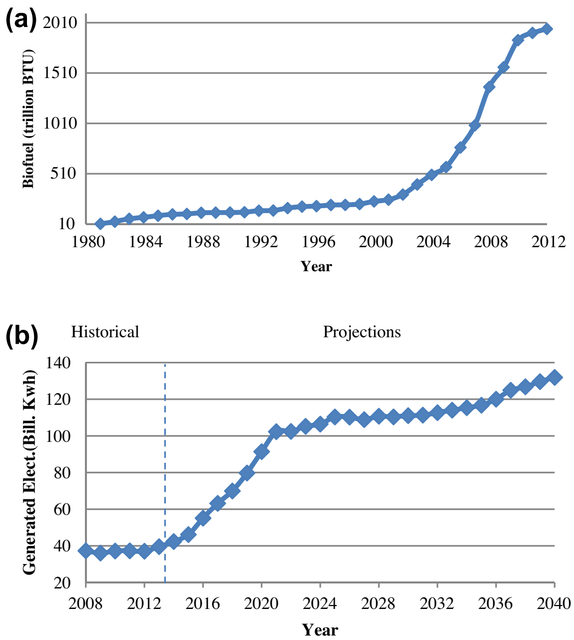

Fig. 1. (a) Historical data about biofuel consumption in the USA during 1980–2012 and (b) projections on electricity generation through biomass co-firing during 2014–2040 (EIA, 2013).