Forest Policy and Economics 85 (2017) 161–171

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Woody residue utilization for bioenergy by primary forest products manufacturers: An exploratory analysis

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ARTICLE INFO

Keywords:
Gate price
Hauling distance
Residue processing capacity
Southern United States
Woody biomass

ABSTRACT

For countries, such as the United States, where one-third of the land area is covered with forests, production of woody biomass-based bioenergy can help lower carbon dioxide (CO_2) emissions, mitigate climate change impacts, and improve energy security. This study involved an exploratory analysis of how current woody residue utilization as well as willingness to use, pay for, and haul additional logging residues varied among mills representing different primary forest products manufacturer types and different processing capacities. A four-contact mail survey was sent in 2012 to 2138 mills in the southern United States. The study used nonparametric independent sample test and analysis of variances to make comparative and explanatory inferences. Approximately 70% of mills utilized woody residues for bioenergy purposes and 11% were willing to utilize additional logging residues to produce electricity. Mills were willing to pay US$11.58/green tonne (t) (2012 dollars) of logging residues at the mill gate. Mills already utilizing woody residues for bioenergy were more likely to improve their utilization, especially those with existing woody residue processing capacities of 1000 to 6000 t/month. Pulp, paper, and paperboard mills and composite wood product mills were the largest woody residues utilizers and were willing to increase use, pay more, and haul additional logging residues over longer distances. These results will be helpful in identifying mills most suitable for increasing utilization of woody residues, guiding investment decisions regarding retrofitting and constructing new facilities for production of bioenergy, and formulating future policies related to biomass-based energy production.

1. Introduction

The pressing need for addressing concerns related to climate change, energy costs, and energy security has increased an interest in renewable energy sources such as woody biomass (McKendry, 2002; Dwivedi et al., 2016). It has become important to reduce carbon dioxide (CO_2) emissions and increase utilization of renewable energy to mitigate the effects of global warming by displacing traditional non-renewable fossil fuels (Dhillon and von Wuehlisch, 2013; Rogelj et al., 2016). At the international level, numerous protocols and agreements, such as the 1997 Kyoto Protocol, 2009 Copenhagen Climate Change Conference, and 2016 Paris Agreement were proposed, amended, extended, and implemented to mitigate climate change impacts by reducing the use of fossil fuels and thus lowering CO_2 emissions (Hepburn, 2007; Bodansky, 2010; Rogelj et al., 2016; UNFCCC, 2016). During 2005–2016, CO_2 emissions decreased by 1.4% in the U.S. and are projected to decrease by 0.2% annually during 2016–2040 due to existing laws and regulations (EIA, 2017).

The U.S. Energy Information Administration (EIA) indicated that approximately 8% of energy in the United States in 2016 was produced from renewable sources and 5% of total production was from biomass alone (EIA, 2017). Furthermore, EIA (2017) projected that an additional 0.1 gigawatts (GW) of electricity from biomass will be produced during 2018–2022. Woody biomass derived from forests accounted for approximately 75% of all biomass (i.e., woody biomass, energy crops, farm waste, solid waste, sewage waste, and other sources) utilized for bioenergy production and was the largest source of renewable energy feedstocks (Perlack et al., 2005; DOE, 2011). Acknowledging the benefits of producing bioenergy from woody biomass, different policies have been developed in the United States to incentivize and facilitate its utilization. The President Bush's Healthy Forest Initiative, the Healthy Forest Restoration Act of 2003, the Omnibus Appropriations Bill of 2003, and the National Energy Policy of 2005 all emphasized the use of woody biomass for addressing domestic bioenergy demand and led to the development of the USDA Woody Biomass Policy in 2005 (Nazzaro, 2005). More recently, Agricultural Acts of 2008 and 2014, commonly known as Farm Bills of 2008 and 2014, also emphasized bioenergy production, challenges associated with the use of biomass for this

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http://dx.doi.org/10.1016/j.forpol.2017.09.012
Received 28 October 2016; Received in revised form 13 July 2017; Accepted 20 September 2017
1389-9341/

purpose, and established funding mechanisms aiming to help facilitate bioenergy production (Hamilton, 2014). For example, Agricultural Act (2014) reauthorized and provided funding of US$880 million for energy programs established in the 2008 Farm Bill, expanded Biorefinery Assistance Program to include bio-based products and renewable chemical manufacturing, and expanded Bio-Preferred Program to include forestry products.

The 2011 Billion-Ton Study Update re-confirmed the 2005 Billion-Ton Study findings that 907 million dry tonnes (t) (one billion U.S. dry tons) of biomass were available for energy production from agricultural and forest lands in the United States, and indicated that this quantity could potentially replace 30% of national petroleum consumption (DOE, 2011). The report also estimated that approximately 117 million dry t of biomass per year were already being extracted from forests and indicated a potential for extracting additional 88 million dry t annually. Utilization of woody residues (e.g., logging and mill residues) alone is projected to account for 18 to 26% of biomass used for bioenergy production by 2031 (Abt and Abt, 2013). Therefore, improved woody residues utilization can have a substantial impact on increasing bioenergy production levels in the United States.

Woody residues such as forest products industry processing residues (i.e., mill residues), logging residues, urban wood waste, and municipal solid waste are important sources of woody biomass that are used for bioenergy production (DOE, 2011; Joshi et al., 2014; Joshi et al., 2015). Currently, only 1.5% of mill residues are not utilized (DOE, 2011) and, therefore, primary forest products manufacturers (mills) need additional sources of woody feedstocks to further increase bioenergy production. It can be argued that a substantial quantity of mill residues currently utilized for purposes other than bioenergy can be diverted from non-energy uses to bioenergy production if cost savings for the mill are demonstrated. However, this quantity might not be adequate to satisfy mill energy needs. Furthermore, while urban woody waste was identified as a potentially less costly source of woody biomass, available quantities were not sufficient to serve as a single feedstock for producing bioenergy in Mississippi (Joshi et al., 2015). Logging residues, on the other hand, were the least utilized resource. Logging residues refer to a forest biomass left after logging operations at the harvest site and include low-quality trees, dead wood, non-commercial trees, and coarse woody debris (Riffell et al., 2011). According to the Billion-Ton Study Update, approximately 47 million dry t of logging residues were economically available for recovery at US$40/dry t in the United States in 2010 (DOE, 2011). Gan and Smith (2006) estimated, based on 1997 Forest Inventory and Analysis (FIA) National Program data, that 36.2 million dry t of logging residues from growing stocks were potentially available in the United States. This quantity of logging residues has a potential to generate 67.5 terawatts per hour (TW/h) of electricity and displace 17.6 million t of CO_2 emissions if used instead of fossil fuels (Gan and Smith, 2006). Almost half of available logging residues (16.5 million dry t) were available in the southern United States (Gan and Smith, 2006), which indicated that forests in southern region would play a major role in supplying bioenergy feedstock based on logging residues. The southern United States has a well-defined and established industrial forestry practices and operations, and the region's wood supply chain is well suited for logging residues recovery and utilization (Conrad et al., 2010).

Historically, forest products industry has utilized woody residues to produce electricity, heat, and extract chemicals for their own use and sale (Guo et al., 2007; Aguilar et al., 2011). In the United States, utilization of woody biomass by the forest products industry for bioenergy purposes has been increasing. For example, wood pellet exports increased by nearly 40% between 2013 and 2014 (EIA, 2015) and accounted for 33% (3.6 million t) of global pellet production (11 million t) in 2014 (USIPA, 2015). Almost all pellets produced in the southern United States are exported to Belgium, Germany, and United Kingdom that use woody pellets to meet their CO_2 emission reduction targets and limit coal use in electricity production (Dwivedi et al., 2016; Singh et al., 2016).

Utilization of woody biomass for bioenergy purposes, however, is associated with economic challenges related to the cost-effectiveness of utilizing this feedstock source not only in terms of extraction and conversion to energy but also a relative competitiveness. Some of the economic challenges related to the cost of converting woody biomass to energy. For example, while the 2011 Billion-Ton Study Update (DOE, 2011) indicated that almost 99% mill residues were utilized in some manner, other studies (Joshi et al., 2014) reported that a large proportion of mill residues (40%) was used for non-energy purposes indicating that mills did not consider this feedstock as highly competitive in terms of energy production, which might require substantial equipment upgrades to facilitate energy production. Other challenges relate to the costs of extracting and transporting woody biomass from a harvest site to a bioenergy facility which can account for up to two-thirds of the total cost of this feedstock (Perez-Verdin et al., 2009; Shivan and Potter-Witter, 2011; Tahvanainen and Anttila, 2011; Wu et al., 2011; Ruiz et al., 2013; Shabani et al., 2013).

Beyond economic aspects, utilization of logging residues to generate electricity has been scrutinized for its impacts on soil productivity and air quality. However, at least 30% of harvested biomass is left on harvest sites because it is not economically feasible to extract it (DOE, 2011). This quantity of biomass contains a sufficient amount of nutrients to maintain soil productivity. For example, Börjesson (2000) indicated that leaving logging residues in the quantity of 0.8 to 2.2 t per hectare (ha) per rotation period was sufficient for regulating essential nutrients such calcium, magnesium, potassium, and phosphorous and Perez-Verdin et al. (2009) found that 30% of logging residues left behind is more than sufficient to meet these nutrient requirements. Additionally, the nutrient losses due to the removal of logging residues can be compensated by costlier methods such as recirculating ashes left after energy conversion (Börjesson, 2000) and fertilization (DOE, 2011). However, the results from the North American long-term soil productivity study did not reveal any uniform and explicit effects on tree growth due to woody biomass removal (Thiffault et al., 2011).

While substitution of biomass for fossil fuels in energy production is credited with lowering CO_2 emissions and carbon neutrality in the long term (Ragauskas et al., 2006; Zanchi et al., 2012), open biomass burning (e.g. camp fires, wildfires) releases substantial quantities of aerosols, which undergo chemical processing during atmospheric transport, and influence air quality with important implications for health and climate (Zhou et al., 2017). However, in terms bioenergy facilities, these emissions can be substantially lowered by installing wood-fired boilers with sedimentation technology to capture particulate matters and reduce their ground level concentrations (Megalos, 2009). Similarly, cyclonic and electrostatic precipitators (dry and wet) are commonly used in biomass burning facilities to reduce aerosols (Megalos, 2009). Therefore, despite concerns related to the impact of woody bioenergy production on air quality, mitigating measures are available to lower environmental impacts of converting biomass to energy.

A limited availability of unutilized mill residues (DOE, 2011), increasing forestry land use (Conrad et al., 2011), increasing forest productivity (Smidt et al., 2012), and growing pellet markets (Conrad et al., 2011; Johnston and van Kooten, 2014) will most likely result in increased availability and potentially greater demand for logging residues as a feedstock for bioenergy production. However, while ample research has been conducted on the utilization of woody residues for bioenergy purposes in general, information on industry specific utilization of woody residues and viability of utilizing additional logging residues to produce electricity by existing mills is limited. The study objective was to address a research gap on the current utilization of woody residues for bioenergy by mills by conducting an exploratory analysis of capacities for processing woody residues to produce bioenergy, mill residues utilization and disposal patterns, mill willingness to utilize additional logging residues, and factors limiting utilization of