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Logging residue supply and costs for electricity generation: Potential variability and policy considerations

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ABSTRACT

This paper applies a spatial allocation optimization model to evaluate logging residue supply potential and costs for bioelectricity generation within the conterminous United States. Simulations are developed to estimate a range in supply potential and costs across a broad range of sensitivity scenarios, including (1) different biomass availability rates based on observed roundwood removals, (2) renewable energy targets set nationally or at a state-level, (3) with and without biomass sourcing restrictions within a state, (4) with and without access to public lands, and (5) policy restrictions on eligible facility types. Under the least restrictive policy scenario (a hypothetical national mandate), total supply is 8.8 million dry tons (MDT) at $20/DT and increases to 32.5 MDT at $80/DT. Results fall within the range of previous logging residue supply studies in the U.S., including the last two Billion Ton reports. Results from this paper offer important policy insight into the potential cost efficiency of a flexible policy design. Sensitivity scenarios show potential supply cost increases that could result from policies imposing regional restrictions, limiting access to public lands, and restricting eligible facilities. Restricting biomass supply sources within state boundaries reduces total supply up to 10% relative to an unrestricted national policy.

1. Introduction

Policy efforts continue to emerge globally to promote renewable energy expansion, with many aiming to achieve a variety of socioeconomic goals, such as greenhouse gas (GHG) emissions reduction, energy independence and security, and rural job development. In the United States and European Union (E.U.), there are several current and planned policies that are expected to increase the total share of renewable energy generation over the next few decades. In the U.S., there are currently more than 50 active state or sub-state mandatory and voluntary programs generally described as renewable portfolio or clean energy standards (DSIRE, 2016). The E.U.'s 2009 Renewable Energy Directive imposed a 20% renewable portfolio standard on its members' energy systems that becomes binding in 2020 (Directive 2009/28/EC). Japan's 2014 Strategic Energy Plan accelerates renewable energy development and energy independence over the long-term (IEA, 2016) and China plans to invest up to $360 billion in renewable energy technologies by 2020 (Forsythe, 2017).

As renewable energy portfolios expand globally, it is possible that various sources of woody biomass could play an important role in meeting this growing demand, especially in the near term as wind, solar, and geothermal technologies mature and penetrate the market. Bioenergy generated from woody biomass is particularly attractive because, unlike the intermittent nature of wind and solar, its use can be continuous (supplying base load generation) and adjusted to meet changes in peak demand. Wood-based biomass sources can include, but are not limited to, woody biomass in municipal solid waste streams, fuelwood purposely extracted from forest stands for energy, and residues generated from milling, thinning, and logging operations (DOE, 2016). The level of integration for different types of woody biomass into renewable energy production will largely depend on accessibility, material composition, logistical costs, and policy signals and incentives.

In the U.S., the role and definition of woody biomass in federal and state energy policies vary considerably, with delineation and eligibility sometimes depending on factors such as feedstock/material type, ownership, silviculture system, harvest type, and land use (Bracmort,

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2015). For some feedstocks, like forest or logging residues,[1] there is less disagreement about the potential role in future bioenergy production due to low market value, fewer GHG emissions concerns versus other feedstocks such as roundwood extracted for energy generation (Perez-Verdin et al., 2009; He et al., 2014) and the lack of leakage issues, as seen with roundwood and milling residue substitution (Latta et al., 2013). Also, there is a considerable amount of potential supply of logging residues in the U.S. that is currently under/unutilized due to a lack of existing market uses, policy or market incentives, extraction costs, and in some cases, infrastructure. Vast areas of U.S. forestlands tend to be rural, without many transport options or local markets, which accounts in part for the large unutilized supply. This transportation element related to logging residues is markedly different from mill residues as most large mills tend to sit on major transportation hubs. As noted by Galik et al. (2009) and He et al. (2014), the majority of logging residues remain in forest stands as land cover under current logging practices. In the U.S., an estimated 4.0 billion cubic feet[2] of logging residue was left unutilized in forests in 2011 (Oswalt et al., 2014). Given the availability of unused logging residues post-harvest and that logging residues may be able to contribute to achievement of renewable energy goals, it is important to better understand supply potential, economic costs, and limitations of this resource.

In addition to the relative availability of logging residues, analysis of logging residue supply potential and economic costs is important due to environmental and GHG considerations. A 2010 European Commission report on conversion efficiency requirements for biomass electricity argues that residue-based forest biomass is more carbon beneficial than other biomass sources, including agricultural energy crops (European Commission, 2010). Other studies also note that logging residues can produce GHG benefits compared to dedicated plantations and large diameter forest stands (Zanchi et al., 2011; Repo et al., 2011). More recently, Matthews et al. (2014) ranks logging residue extraction as a “moderate” GHG emission risk relative to other forest management practices which reallocate harvested wood from solid wood products to bioenergy. For context, this study identified “high risk” scenarios which shifted roundwood harvests from wood product markets to bioenergy and resulted in adverse GHG impacts. Non-GHG implications of residue harvest also warrant consideration, however. Recent studies have focused the relationship between residue extraction and soil, hydrological, and habitat function (Scott and Page-Dumroese, 2016) with a focus on providing operational guidelines to minimize potential impact (Abbas et al., 2011).

Finally, focusing on logging residues is important because the few existing published estimates of potential U.S. logging residue supply vary greatly due to differences in underlying data, related assumptions, and modeling approaches. For example, large differences in projected logging residue supply potential are seen in the 2011 and 2016 Billion Ton Reports (DOE, 2011, 2016) (the next section presents a more detailed review of the literature). This paper develops and applies a spatial allocation optimization model to assess potential logging residue supply, and an array of different factors that can influence that supply, at different biomass price points across a range of hypothetical U.S. renewable electricity policy scenarios. The modeling framework specifically targets increased utilization of logging residues for energy generation at existing co-firing capable coal and biomass boilers, which focuses the analysis on the marginal costs of logging residue utilization for energy generation irrespective of the supply of alternative feedstocks.

Furthermore, given uncertainty in future U.S. renewable energy policy design, a sensitivity analysis is developed that explores different policy parameters. These sensitivity scenarios include (1) restricted access to logging residues on public lands (for a policy design that favors public land utilization); (2) restricting the analysis to co-firing biomass at coal-fired boilers only (meaning no biomass-only boilers, consistent with a policy that seeks to reduce coal-based electricity generation at existing facilities), and (3) state-level renewable electricity mandates, with and without restricted biomass sourcing. Restricted biomass sourcing would be consistent with a protectionist state-level policy that favors biomass sources procured from within state boundaries. This scenario design allows for a direct assessment of potential cost inefficiencies of establishing renewable energy targets at a state level or restricting eligible biomass resources within states.

The spatial allocation framework and custom scenario design presented in this paper offer several contributions to the literature, including:

1) The use of physical constraints that reflect potential logging residue supply limitations consistent with observed roundwood removal rates in the U.S. Each supply estimate is calibrated to average observed roundwood removals evaluated over a twenty year historic time frame (between 1992 and 2012) instead of a single point in time like previous studies (e.g., DOE, 2011).
2) Direct linkage between supply points on the landscape (forest resources by county, forest type, and ownership class) and demand points (coal or biomass boilers capable of generating electricity from woody biomass).
3) Comparison of supply potential with and without assumed policy restrictions (e.g., limiting access to logging residues on public lands and restricting end-use to coal-fired boilers only).
4) A direct comparison of potential logging residue supply and costs under renewable electricity mandates set at national and state scales, with and without restrictions on local sourcing.

Our analysis applies static (one time-period) simulations of different hypothetical policy scenarios to reflect potential future logging residue supply and costs under different assumptions. Thus, we do not attempt to project future outcomes under assumptions of macroeconomic growth, future harvest levels, or bioelectricity demand. Results from this study are compared to previous research, indicating how logistical constraints, policy design and whole-tree harvest levels can dramatically increase or decrease residue supply potential.

2. Background and previous literature

Previous studies evaluating wood bioenergy markets mainly focus on the potential supply of residues at the roadside of logging operations (Milbrandt, 2005; Perlack et al., 2005; Daystar et al., 2013) while others estimate both supply and demand-side characteristics of an aggregated bioenergy market inclusive of logging residues (Gan and Smith, 2006; Galik et al., 2009; DOE, 2011, 2016; He et al., 2014).

Given the potential importance of logging residues as a feedstock for energy generation purposes, there are few U.S. national-scale assessments of logging residues that project costs and supply potential under alternative policy, environmental, and market conditions. A few previous studies included logging residues in national or regional assessments of bioenergy supply potential in the U.S., though these studies often combine logging residues into analyses of multiple feedstocks and are focused more on understanding the systematic environmental or market impacts of the policy, where logging residues are part of a broad portfolio of feedstocks (Wu et al., 2011; DOE, 2016). Daigneault, Sohngen, and Sedjo (2012) use a global timber model to evaluate the global impacts of U.S. biomass energy expansion, and show how including logging residues in the portfolio can improve the net carbon outcomes of this expansion. Latta et al. (2013) use a detailed model of the U.S. forestry and agriculture sectors to examine several hypothetical bioenergy expansion policies and find that inclusion of logging residues into the bioenergy feedstock portfolio can improve environmental

[1] The residual portion of trees cut for roundwood products and trees killed in the process of extracting roundwood products.

[2] Approximately 113 million cubic meters.