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A multi-sector intertemporal optimization approach to assess the GHG implications of U.S. forest and agricultural biomass electricity expansion

Gregory S. Latta[a,*], Justin S. Baker[b], Robert H. Beach[b], Steven K. Rose[c], Bruce A. McCarl[d]

[a] Oregon State University, Department of Forest Engineering, Resources and Management, Corvallis, OR 97331, USA
[b] Research Triangle Institute, Agricultural, Resource & Energy Economics and Policy Program, Research Triangle Park, NC 27709, USA
[c] Electric Power Research Institute, Energy and Environmental Analysis Research Group, 2000 L Street NW, Suite 805, Washington, DC 20036, USA
[d] Texas A&M University, Department of Agricultural Economics, College Station, TX 77843, USA

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ABSTRACT

This study applies an intertemporal partial equilibrium model of the U.S. Forest and Agricultural sectors to assess the market, land use, and greenhouse gas (GHG) implications of biomass electricity expansion. Results show how intertemporal optimization procedures can yield different biomass feedstock portfolios and GHG performance metrics at different points in time. We examine the implications of restricting feedstock eligibility, land use change, and commodity substitution to put our results in the context of previous forest-only modeling efforts. Our results highlight the importance of dynamic considerations and forest and agricultural sector interactions on projecting the GHG effects of biomass electricity expansion in the U.S.

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* Corresponding author. Tel.: +1 541 737 6264.
E-mail address: greg.latta@oregonstate.edu (G.S. Latta).

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Introduction

With rising concern over future energy security and the environmental footprint of the global energy system (including climate change concerns), energy policy is moving towards efforts that encourage or require that a larger proportion of energy generation be derived from renewable sources. In the U.S., there are examples of such policies at both the national and state levels. Nationally, the U.S. currently has the renewable fuels standard (RFS2; enacted under the Energy Independence and Security Act (EISA) of 2007 to expand the original RFS program created under the Energy Policy Act of 2005), which mandates increased levels of first and second generation biofuel production. In addition to increasing renewable fuel volume requirements and establishing new categories of renewable fuel (biomass-based diesel, cellulosic biofuel, and advanced biofuel in addition to traditional renewable fuel), RFS2 requires that each category of renewable fuel yield a minimum percentage GHG reductions relative to the petroleum fuels being replaced. However, there petroleum fuels being replaced. However, there renewable electricity.

At the state level, existing mandatory and voluntary programs include a wide range of utilization requirements and other incentives encouraging the adoption of renewable energy sources. Such energy sources include solar, wind, biomass, hydroelectric, geothermal, hydrogen, waste and waste-based gases, and ocean-based heat and energy. Some existing policies favor investment in specific renewable electricity sources, and are currently seen in a number of states; these include tax credits, grants, loan guarantees and other price incentives (a detailed discussion of existing policies is found in Aguilar et al., 2011). Other policy efforts simply establish portfolio standards and let the market determine the optimal generation mix. For example, the state of Oregon established a renewable portfolio standard (RPS) for electric utilities and retail electricity suppliers, mandating the use of a variety of renewables sources for different targets depending on a utility's size. Another example, is the Massachusetts RPS that requires all retail electricity suppliers to provide a certain percentage of annual kW h sales from specified classes of renewable sources. California's RPS is yet another example, which requires that 33% of the state's electricity come from certified renewable sources, including biomass, by 2020. The California policy also contains a cap and trade program that includes compliance offset protocols for GHG emission reductions or sequestered carbon (from, for example, tillage change, afforestation or improved forest management) that may be used by regulated entities to meet a percentage of compliance obligations.

With many states already having renewable targets and federal renewable goals likely, biomass could play a prominent role in a portfolio-based electricity policy. The rationale for promoting renewable electricity sources is that utilization of such energies in lieu of fossil fuels could yield numerous benefits, including GHG emissions reductions and future climate change mitigation, local air and water quality improvements, energy security (for states without abundant fossil fuel resources), and rural economic development, including employment, and farm and forest income opportunities.

Of particular note is the potential role of electricity derived from the combustion of biomass (henceforth referred to as biopower) to meet policy-driven renewable electricity demands. In addition to being derived from renewable resources, biopower offers a relatively low-cost renewable electricity source (Brown and Baek, 2010; Touš et al., 2011). While biomass feedstocks are higher cost than conventional fossil fuels on an energy equivalent basis, biomass can often be co-fired directly with coal at existing facilities with low to no up-front technological investment. This can make biopower a cost-competitive source of renewable energy in the short-term relative to renewables that require more significant capital investments for both generation and distribution (e.g., wind, concentrated solar thermal, solar photovoltaic, tidal). Other studies have shown that biopower offers greater GHG mitigation potential than biofuel production using the same feedstock (Thomson et al., 2009; Farine et al., 2012; Soimakallio et al., 2009; Campbell et al., 2009). In addition, Baker et al. (2010) showed that renewable energy and climate mitigation policies in the U.S. could lead to large income benefits for U.S. farmers and foresters.

However, there is a lack of consensus of the level of GHG reductions associated with replacing fossil fuel electricity generation with biopower. Some biomass energy policies assume a priori that biopower is 'carbon neutral', meaning that the combustion of biomass does not contribute to atmospheric GHG concentrations. More recent research has questioned the carbon neutrality of biopower, suggesting