BIO-BASED ELECTRICITY: HOW BIOMASS RESOURCES CAN SUPPORT RENEWABLE ELECTRICITY POLICIES

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In recent year interest in renewable sources of energy has intensified as concerns over environmental issues and costs associated with traditional energy sources has increased. The Energy Policy Act of 2005 (EPACT 2005) first established the Renewable Fuel Standard (RFS), mandating that renewable fuels be blended to U.S. fuel supplies. In 2007, the Energy Independence and Security Act of 2007 (CPO 2007) expanded the RFS. On the local level, states, led by California, have started designing low carbon fuel standards (LCFS), which encourage the production of renewable fuels (Farrell 2007). The RFS and LCFS have focused on supporting renewable energy sources for the production of transportation fuels. On the electricity side, 33 states have enacted Renewable Portfolio Standards (RPS) (EPA 2009), mandating that certain amount (or a percentage) of electricity produced in the state, be produced with renewable sources. Biomass has been identified as the major renewable source to support RFS and LCFS. Less quantitative research has addressed the role biomass resources could play in supporting renewable electricity portfolio standards.

Sources of biomass considered as feedstocks for electricity production include agricultural residues, hard- and softwoods, herbaceous energy crops, and mill and urban wood residues. Agricultural residues include corn stover and wheat straw and represent the portions of the plant that remain once the crop itself has been harvested. In theory, the only costs to obtaining agricultural residues involve collection, transportation, and storage, making agricultural residues a promising low-cost, near-term biomass feedstock. Hard- and softwood biomass includes logging residues, forest thinnings, and short-rotation woody crops such willow and poplar trees. Like agricultural residues, forest residues represent a currently available feedstock where the feedstock cost is composed primarily of collection, transportation, and storage costs. Short-rotation woody crops grown in tree farms could increase the supply of woody biomass, but likely at a higher cost than forest residues. Herbaceous energy crops refer primarily to perennial grasses such as switchgrass and miscanthus. These crops may be grown on marginal or degraded cropland without requiring heavy pesticide or fertilizer application, but due to uncertainty regarding energy crop yields and cellulosic feedstock prices, it may be difficult for energy crops to make a significant contribution to meeting demand before a mature market for cellulosic biomass has developed. Urban wood waste and mill residues represent perhaps the most economically favorable near-term feedstock. Like agricultural and forest residues, these feedstocks represent waste streams with no production cost, with the added advantage of higher density and reduced collection costs compared to other residues.

Haq (2002) examines the availability of biomass for electricity generation within the context of the Energy Information Administration's (EIA) National Energy Modeling System (NEMS), which is used to develop EIA's Annual Energy Outlook. By 2020, over 400 million dry tons of biomass are expected to be available annually at a price of $5 per million Btu, or around $80 per dry ton. However, only urban wood waste and mill residues are expected to provide a significant amount of energy at prices below $2 per million Btu, with the total supply from these sources reaching 25 million dry tons at low prices. Haq estimates that biomass would be used to generate 60 billion kWh in the 2020 reference case (on the order of 1% - 2% of total projected electricity generation), but that the generation from biomass would climb to 520 billion kWh under a 20% Renewable Portfolio Standard as higher-cost feedstocks such as energy crops and forest residues are increasingly used to meet renewable electricity mandates.

Technologies for converting biomass into electricity include cofiring biomass with coal, dedicated biomass combustion, and biomass gasification. Cofiring biomass and coal has a number of advantages compared to combusting either fuel individually. Adding biomass to the fuel mix used by coal-fired power plants can reduce emissions of fossil CO_2, SO_x, and NO_x compared to coal combustion (Tillman 2000). Compared to combustion of biomass alone, cofiring can limit capital investment requirements while still allowing for the use of power plants with large capacities that might otherwise be prohibited by capital costs or limited local feedstock availability. Cofiring also limits the build up of ash and alkali metals that may disrupt dedicated biomass combustion, especially in the cases of agricultural residues and herbaceous energy crops like switchgrass (Morrow 2006). Most RPS, however, do not include biomass co-firing in their provisions. Dedicated biomass combustion allows for conversion of biomass into electricity without necessitating fuel blending. The Emissions & Generation Resource Integrated Database (eGRID) contains 350 generators that use biomass as their primary feedstock, with over 95% of the net generation coming from municipal solid waste or other solid wood wastes. Biomass combustion tends to be restricted to relatively small plants, with an average capacity of 17 MW and a maximum capacity of 90 MW across all biomass-fueled generators contained in the database (EPA 2010). Biomass may also be used as a feedstock for power generation via an integrated gasification combined cycle (IGCC) system that uses a gasifier to convert the feedstock into syngas (a mixture of H_2, CO, and CO_2), which is then used to power a gas turbine. Waste heat is used to power a steam turbine that increases generation capacity. Biomass gasification is characterized by higher capital costs, higher conversion efficiencies, and easier modification for carbon capture and sequestration than combustion.

If biomass is to be used to support renewable electricity policies, several questions should be addressed. Different conversion technologies have different strengths and weaknesses and may support grid operations in different ways. It is thus important to understand which service within the electricity markets is bio-based electricity most suitable for, and what technology pathways are most appropriate to provide these services. Using biomass to meet different types of electricity demands can lead to different cost and emissions impacts. If biomass is used to meet base load demands, it may be possible to rely heavily on cofiring with coal, a conversion option with limited capital investment requirements. Base load demand, however, is generally met with low-cost electricity, so the economic benefits of using biomass to meet these demands may be limited. Meeting peak electricity demands with biomass, on the other hand, could allow biomass to offset more carbon intensive electricity generation, but could necessitate high-cost conversion technologies such as gasification. If biomass is coupled with variable and intermittent renewable sources, the effective supply of renewable electricity could be stabilized, but the impacts of switching biomass powered generation on and off to supplement solar or wind generation are unclear. Finally resource security needs to be better understood before significant investments in bio-based electricity take place. Because studies estimate that a significant amount of biomass may be available within the United States at modest costs, biomass is viewed as an energy source with positive energy security impacts. However, if energy crops and crop residues represent a significant percentage of domestic biomass supply, then biomass availability may be affected by the same factors that create variability in agricultural yields, with a coefficient of variation estimated to be 0.15 or more throughout much of the Midwest and Southeast where energy crops are projected to be grown.

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