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Drivers of biomass co-firing in U.S. coal-fired power plants

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ABSTRACT

Substantial knowledge has been generated in the U.S. about the resource base for forest- and other residue-derived biomass for bioenergy including co-firing in power plants. However, a lack of understanding regarding power plant-level operations and manager perceptions of drivers of biomass co-firing remains. This study gathered information from U.S. power plant managers to identify drivers behind co-firing, determine key conditions influencing past and current use, and explore future prospects for biomass in co-firing. Most of the biomass used in co-firing was woody biomass procured within 100 km of a power plant. Results show that the most influential co-firing drivers included: adequate biomass supply, competitive cost of biomass compared to fossil fuels, and costs of biomass transport. Environmental regulations were generally considered second-most influential in decisions to test or co-fire with biomass, but were of high importance to managers of plants that are currently not co-firing but may in the future.

1. Introduction

Combustion of fossil fuels provided about 84% of total energy and about 69% of electricity consumed in the U.S. in 2010 [1]. Coal is the most highly used fuel for electricity production in the U.S.; about 1000 Mt of coal were fired to generate electricity and heat in 2008 [2]. Since the early 1990s, coal has steadily provided about 51% of electricity annually consumed in the U.S. since the early 1990s [3,4].

Although non-renewable fossil fuels dominate the energy sector, energy from a variety of biomass sources provided about 3% of total energy consumption in 2008 and exceeded 4% for the first time in 2009 [5]. Among different bioenergy feedstocks, woody biomass supplied the greatest share of renewable energy – about 53% in 2010 [1]. Woody biomass was used for energy primarily in the forest products industry (68%), for electric power generation (9%), and for residential (20%) and commercial (3%) heating [5]. Woody biomass used for energy production comes primarily from two sources: residues generated in the manufacture of forest products and fuelwood used in the residential and commercial sectors. Residues from the forest products manufacturing include primary and secondary mill by-products generated in making lumber, veneer and panels, and black liquor generated in the pulping process, among others. Fuelwood is wood that is harvested from forests and used directly for residential and commercial heating, as well as electric power production [5]. Other types of woody biomass such as urban wood residues are available at lower volumes, limited to densely populated areas, and are often already used in

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composting or unavailable because of excessive contamination [5].

Various types of technologies can be used to convert biomass to energy. These include: (1) direct firing or co-firing biomass for electricity, heating and cooling, (2) production of liquid biofuels, and (3) gasification of biomass [6,7]. Co-firing refers to the practice of using biofuels as a supplementary energy feedstock in high-efficiency utility boilers [8,9]. An estimated 86 coal-fired power plants used some biomass as of 2007 [2,10]. Co-firing biomass with coal is a popular option because many coal-fired electric plants can use biomass in existing fuel storage and handling systems with relatively minor modifications [3,11–14].

Past research has assessed the conversion of fuel handing systems and boilers to accommodate co-firing of biomass with coal [12,15]. A number of biomass resource assessments at varying spatial scales have evaluated the feasibility of co-firing across the U.S. [4,16,17]. One limitation of these studies is a lack of understanding of factors that influence managers in deciding whether or not to co-fire. For instance, Aguilar et al. [17] estimated resource availability and the likelihood of co-firing in counties of the U.S. Northern Region using a combination of geo-referenced biomass resource and socio-economic secondary data. However, there is still a need to ask plant managers directly for reasons why power plants in the U.S. have or have not incorporated biomass to be co-fired with coal. A direct survey of power plant managers was deemed necessary to determine drivers behind past decisions and prospects for co-firing in the future.

There were several reasons for investigating coal-fired power plants. First, biomass (most of it woody biomass) is the main source of renewable energy in the U.S. and an important share is used by the electric generation sector. Second, establishment of dedicated plants burning only biomass is rare given economic and logistic challenges, thus, co-firing has emerged as a feasible alternative. Third, co-firing is already occurring in the market with success, yet the literature discussing factors driving the decision process at the power plant-level is scarce [18]. Fourth, biomass use has been reported to be influenced by local (power plant-level) perceptions of feasibility and interest, not solely on alternative energy prices or output from other industries [19].

2. Aim and objectives

The aim of this study was to identify salient drivers behind consideration, testing, and implementation of biomass co-firing operations in U.S. power plants. Specific objectives included to: (1) identify factors influencing biomass co-firing in U.S. power plants, (2) determine the drivers behind decisions to co-fire, (3) determine principal drivers behind current and past co-firing testing and implementation, and (4) identify factors most likely to influence future decisions to use biomass in co-firing.

3. Theoretical framework

Identification of drivers that influence past, current and future co-firing was framed within industrial regional science. Regional science suggests that industries, such as power generation, tend to locate in areas according to internal, external, and location-specific drivers. Internal drivers include firm-specific conditions such as a particular production technology, management, ownership structure, growth rate, employment and profits, among others. External factors include government policy and regulations, regional economic structure, and technological progress. Location-specific factors refer to absolute and relative characteristics of the location such as access to input materials, distance to customers and suppliers, and the presence of support services [16]. This framework is similar to the triangular model of clean technology adoption that suggests decisions to adopt environmentally-friendly technologies are a function of the interaction between external actors and factors, firm internal factors and characteristics of the technology [20].

Internal, external and location-specific drivers influence decisions to adopt new practices, such as use of biomass for co-firing with coal. One of the most important internal drivers is operational and maintenance costs of co-firing equipment. The significance of this driver greatly depends upon the current fuel delivery system and boilers used by a particular plant. Stoker, cyclone, and fluidized bed boilers are the most adaptable to co-firing due since they can burn coarser fuels and fuels with higher moisture content [3,12]. Other internal drivers include voluntary commitments to renewable energy standards and availability of internal corporate capital investments for conversion to co-firing. Regulatory drivers are major external drivers and include state and federal regulations regarding biomass procurement and use, carbon dioxide emissions and other greenhouse gases, and criteria pollutants, as well regulations concerning implementation of state-level renewable energy portfolio standards [17]. Additional external drivers include state or federal subsidies and availability of capital for investment. Location-specific factors are characteristics of the area surrounding individual power plants. Three of the most important location-specific drivers are the cost of biomass compared to coal, adequate year-round biomass supply, and cost of biomass transport [21,22]. The technical feasibility of co-firing biomass is highly dependent upon efficient transport of biomass from the source to the power plant [12,16,23].

4. Methods

A questionnaire was developed and reviewed by researchers and practitioners at the University of Missouri and the U.S. Forest Products Laboratory and pre-tested among a group of 10 power plant managers in July–October 2011. The survey instrument consisted of four sections to gather information about (1) power plant descriptors, (2) key factors that influence the decision to co-fire across power plants, (3) drivers for power plants that have co-fired or tested with biomass, and (4) drivers for power plants that have not tested or co-fired but may either begin or consider doing so in the future. To distinguish between factors that affected decisions to test/stop testing or co-fire in the past and those that may influence a decision to begin co-firing in the future we asked respondents to identify their power plants in one of three categories. These reflected whether a power plant has tested co-firing in the past, is

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