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# Co-firing coal with wood pellets for U.S. electricity generation: A real options analysis

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## HIGHLIGHTS

- Real options analysis indicates co-firing is not currently economically feasible within the U.S.
- The recent U.S. natural-gas boom is likely hindering the adoption of co-firing.
- For co-fired adoption, government incentives or an increase in natural-gas prices are necessary.

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## ABSTRACT

In contrast to EU, U.S. electric utilities are not employing the bioenergy technology of co-firing wood pellets with coal. This difference in employment patterns is explored within a real options analysis (ROA) for possible U.S. utilization of wood pellets, considering fuel-price series from 2009 to 2014. For analysis, these series are divided into two sub-periods based on different market conditions: Infancy (2009–2011) and Substitution (2012–2014). ROA indicates co-firing wood pellets with coal is feasible considering adoption during wood pellets' infancy, under low discount rates, and long power-plant lifespans. A portfolio effect of employing multiple fuels underlies this result. However, co-firing is not currently economically feasible. The different adoption decisions are likely a consequence of recent cheap and abundant U.S. natural gas. For co-fired wood pellets to be feasible, government incentives and/or a market increase in natural gas prices appear necessary.



## 1. Introduction

Energy production from biomass has the potential to reduce greenhouse gas (GHG) emissions, diminish reliance on non-renewable fuels, and aid in bridging the transition from fossil fuels to low or zero carbon energy sources. Despite its promise, biomass accounts for less than 2% of total U.S. electricity generation. Coal has historically been the primary U.S. fuel for generating electricity, accounting for approximately half of all electricity consumed over the past two decades (EIA, 2013b). However, with the advent of commercially viable hydraulic fracturing technologies coupled with horizontal drilling methods along with new EPA $CO_2$ emission restrictions, the future dominance of coal for U.S. electricity production may be in question.

Recent estimates by the U.S. Energy Information Administration (EIA) project natural gas could supplant coal by 2040 as the primary fuel for U.S. electric power generation (EIA, 2013d). The effects of rapid maturation of the U.S. shale-gas sector are already being felt in the coal industry. Between 2008 and 2012, net generation by electric utilities from natural gas increased from 320 to 505 million megawatt hours, while production from coal dropped from 1500 to 1100 million megawatt hours. Over the same time period, 23 new natural gas power plants were brought online while 33 coal plants have been closed (EIA, 2012b).

This shift in fuel types may have impacts on biomass demands, which leads to the following underlying hypothesis: The U.S. natural gas boom is hindering the adoption of biomass. The increased supply of low-cost natural gas and the resulting decline in coal prices and its associated volatility has significantly reduced or eliminated incentives for the adoption of wood pellet biomass. For investigating the hypothesis, this study is the first to employ real options analysis (ROA) in assessing the feasibility of co-firing wood pellets when accounting for volatile energy markets and shifting energy patterns. The unique insight is energy-price patterns are

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analyzed by separating data into two periods yielding different results and supporting the hypothesis that natural gas adoption blocks biomass wood pellets adoption. The first period, called the Infancy period, considers the early stage when the U.S. wood pellet industry experienced a rapid increase in prices. This Infant-Industry period was then followed by the Substitution period, where relatively cheap natural gas eroded coal's dominance in U.S. power plants. Results suggest despite the thriving U.S. wood pellet industry satisfying EU demand (Anich et al., 2012), the price differential between wood pellets and coal along with the muted levels of price volatility in these markets renders co-firing unsupportable. Without shifts in the coal and natural gas markets, wood pellet co-firing would likely be economically advantageous from the perspective of reducing fuel input-price volatility. Implications indicate U.S. co-firing under current market conditions becomes feasible only if subsidies or taxes designed to reduce GHG emissions are implemented.

In contrast to the United States, this shift from coal to natural gas is not mirrored in the EU, where coal usage for electricity generation has increased (EIA, 2013c). Even with stricter environmental regulations, including the 2009 Renewable Energy Sources (RES) directive (Sikkema et al., 2011), there are a number of European market forces encouraging increased coal usage. These include (1) sharply lower coal prices due to decreased U.S. demand, (2) lagging natural gas infrastructure and pipelines, and (3) relatively higher regional natural gas prices and unfavorable existing contracts (Fidler, 2014). Other forces are too low of a carbon tax favoring coal over gas (Carbon Tax Center, 2014) and increased renewable energy production crowding out expensive gas-fired power instead of coal plants (Tweed, 2014).

This difference in market conditions between the U.S. and the EU points to the importance of what can be termed the 3-Ts in policy: Timing, Type, and Transience. Timing, is concerned with when a policy should be instigated, Type is determining the correct kind of policies (e.g., standards, subsidies, or taxes), and Transience is concerned with the length and consistency of a policy. While significant research has investigated the types of governmental policies, little effort is directed toward to the timing and transience of energy policies. This study is directed toward the timing component by offering empirical results demonstrating the importance of market conditions underlying the likely adoption of an alternative energy. Specifically, the employment of wood pellets by U.S. power companies is investigated under alternative natural gas market conditions.

The remainder of the paper is organized as follows: First a brief discussion on the nature of wood pellet biomass in conjunction with natural gas is presented, which is followed by a discussion on the utility managers' interest in reducing the price volatility of their fuels. A literature review then completes this section. Section 2 outlines the theoretical framework, where the optimal threshold rule for employing an alternative fuel (co-firing) based on ROA is then derived. This is followed by empirical analysis including data description with associated data adjustments based on unit-root analysis. The empirical application of the optimal threshold rule is then developed. Section 3 presents the results along with the associated policy implications. In Section 4, the analysis associated with dividing the time period into two periods (Infancy and Substitution periods) is discussed. The effect of implementing taxes on coal and subsidies on wood pellets is then discussed. Conclusions and policy implications are presented in Section 5.

### 1.1. Wood pellet biomass

Biomass in general and wood pellets in particular are a renewable resource with relatively low GHG emissions, which can be co-fired in coal plants (Kinney, 2012). Lempp (2013) provides an excellent technology brief on the advantages and disadvantages for biomass co-firing. Advantages include reduced GHG emissions and the incremental investment of co-firing is significantly lower than the cost of dedicated biomass power. Disadvantages include competition with vehicle biofuels for biomass and contracting for a stable cost-effective biomass supply. Wood pellets can mitigate the disadvantages by providing a consistent uniform supply, which lowers biomass contracting costs as well as the cost of co-firing. Specifically, wood pellets are pelletized woody biomass, which increases wood density yielding higher energy and lower moisture content as well as a uniform size for hauling, handling, and usage (Spelter and Toth, 2009). With pelletization, barriers to incorporating biomass in power production are reduced (Lempp, 2013). Co-firing, in contrast to constructing a solely biomass-fueled plant, is a relatively inexpensive option due to the minor capital costs required for using wood pellets in existing coal power plants (Zhang et al., 2009). At low levels of co-firing these biomasses may still have a larger carbon footprint relative to natural gas, but a maturing biomass sector may have the potential to substantially reduce coal usage. In such a case, co-firing could then carbon-compete favorably with natural gas. Biomass co-firing can then be considered as a transition option toward a carbon-free power sector (Lempp, 2013). For this to occur, the biomass sector must be established and the abundance of U.S. natural gas may be preventing this establishment.

While the full environmental impacts of this abundant supply of natural gas from hydraulic fracturing are unknown, the lower levels of carbon dioxide and nitrogen oxide released from burning natural gas compared to coal is viewed as an important step toward mitigating climate change (EIA, 2012d). However, this emergence of cheap and abundant U.S. natural gas may be detrimental to the adoption of lower carbon renewable fuels with no potential fracturing environmental consequences such as biomass.

When considering their supply of fuels, electric power utility managers have the objective to minimize the expected fuel costs and protect themselves from supply shortages. They attempt to achieve this objective by having a range of contract lengths for their coal supply, which yields a portfolio of contracts. These contracts lengths range from five to10 years, two to three years, and annual or shorter periods. The managers also have layered contracts in place of differing durations, so they roll off at a variety of times. These contract lengths and layering result in stochastic prices, which managers consider when making fuel purchases. In terms of economics, co-firing has a potential of reducing the stochastic nature of fuel prices through a portfolio-effect benefit with two fuel sources reducing the price volatility. Managers then have an additional source for mitigating fuel-price volatility by employing co-firing coal with wood pellets. This potential reduction in volatility has value, which leads to a positive option value. In a similar vein, Vedenov et al. (2006) demonstrate how the price volatility of gasoline blended with ethanol is lower than conventional gasoline and when considering both price levels and volatilities, gasoline wholesalers may have an incentive to adopt ethanol blended gasoline despite the higher costs.

### 1.2. Literature review

Employing ROA to co-firing will account for this portfolio effect with the objective of highlighting the adoption decisions of U.S. power-plant managers. Results supporting the hypothesis that a natural gas boom is hindering biomass adoption are founded on previous literature applying ROA to energy markets. Teisberg (1993) uses a real options model to examine investment in electric utilities, and determines when there are lead times and policy uncertainty, utilities are better off investing in smaller projects with shorter lead times or delaying investment all together. In the