Energy Policy 73 (2014) 631–644

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Biomass for electricity in the EU-27: Potential demand, CO_2 abatements and breakeven prices for co-firing

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HIGHLIGHTS

- Technical potential of biomass (demand & CO_2 abatement) in European electricity.
- Calculation for co-firing & biomass power plants; comparison with potential biomass supply in EU-27 countries.
- Calculation of biomass and CO_2 breakeven prices for co-firing.
- Potential demand is 8–148% of potential supply (up to 80% of demand from co-firing).
- High potential abatement from co-firing (up to 365 Mt/yr); Profitable co-firing with €16-24 (25–35) biomass price for €20 (50) CO_2 price.

ARTICLE INFO

Article history:
Received 6 February 2014
Received in revised form
10 May 2014
Accepted 6 June 2014
Available online 11 July 2014

Keywords:
Biomass
Electricity
EU ETS

ABSTRACT

This paper analyses the potential of biomass-based electricity in the EU-27 countries, and interactions with climate policy and the EU ETS. We estimate the potential biomass demand from the existing power plants, and we match our estimates with the potential biomass supply in Europe. Furthermore, we compute the CO2 abatement associated with the co-firing opportunities in European coal plants. We find that the biomass demand from the power sector may be very high compared with potential supply. We also identify that co-firing can produce high volumes of CO_2 abatements, which may be two times larger than that of the coal-to-gas fuel switching. We also compute biomass and CO2 breakeven prices for co-firing. Results indicate that biomass-based electricity remains profitable with high biomass prices, when the carbon price is high: a Euros 16–24 (25–35, respectively) biomass price (per MWh_{prim}) for a Euros 20 (50, respectively) carbon price. Hence, the carbon price appears as an important driver, which can make profitable a high share of the potential biomass demand from the power sector, even with high biomass prices. This aims to gain insights on how biomass market may be impacted by the EU ETS and others climate policies.

1. Introduction

In adopting the 2001 Directive (2001/77/EC) on the promotion of electricity produced from renewable energy sources, the European Union demonstrated its commitment to renewable energy. This was confirmed in 2008, with the Climate and Energy Package, extending the EU's climate policy beyond 2012. The package includes three targets to be reached by 2020: a 20% reduction in greenhouse gas (GHG) emissions from the 1990 level, 20% of renewable resources in energy consumption, and a 20% increase in energy efficiency.[1]

Biomass is increasingly acknowledged to be one of the main renewable energy sources (RES) for achieving EU targets. The use of biomass would not only increase the proportion of RES, but it would also reduce CO_2 emissions, since biomass is considered to be carbon-neutral.[2] There are also a number of concerns about the sustainability of bioenergy, including potential impacts on food/feed, land-use changes, and reduced biodiversity. While such negative externalities are difficult to eliminate, most of them are

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[1] The Climate and Energy Package, which was first discussed in 2008, entered in force in 2009 through adoption of Directive 2009/28/EC. EU objectives on biomass has been further defined in the biofuels Directive (2003/30/EC), and in the Biomass Action Plan of 2005.

[2] See EFC (2010) and DECC-SAP (2011) for discussions about current CO_2 emissions from burning biomass. See also Sjølie and Solberg (2011) and Caurla et al. (2013).

http://dx.doi.org/10.1016/j.enpol.2014.06.007
0301-4215/

considerably reduced by using lignocellulosic biomass. Among the positive effects of lignocellulosic biomass is the fact that it does not enter into competition with food (other than indirectly, through land-use) unlike energy crops such as sugar beet or maize. This also reduces concerns about land-use, since a large proportion of feedstocks come from agricultural and forestry residues. Moreover, as with forestry, remaining concerns should be addressed through certifications (ECF, 2010).

Biomass-based electricity is of great interest because it enables RES to be developed with little or no investment, through the co-firing of biomass in coal plants. Given the high percentage of coal in European electricity, co-firing provides great opportunities for increasing the share of renewable electricity in the near-term, through reliable technologies that are not subject to problems of intermittency. With respect to CO_2 emissions, co-firing can be considered as a highly effective abatement measure, because it substitutes biomass, with zero emissions under the European Union Emission Trading Scheme (EU ETS), for coal, which produces the highest CO_2 emissions.[3]

This paper investigates the question of biomass usage in European electricity, and interactions with climate policy and the EU ETS. We estimate the potential biomass demand from existing power plants in the EU-27, we match our estimates with the potential biomass supply, and we derive the CO_2 abatement from co-firing. We also compute biomass and CO_2 breakeven prices for co-firing. To date, very few papers have investigated the question of how much biomass can be used in European electricity. Of these, Berggren et al. (2008) estimate the technical potential for biomass co-firing in Poland. This paper focuses on matching the potential biomass supply in Poland with estimated opportunities for biomass co-firing in existing coal plants. The authors also derive the CO_2 abatements from co-firing. The results indicate that about 4 Mt of CO_2 can be abated each year in Poland through biomass co-firing in coal plants. Hansson et al. (2009) estimate the potential biomass demand from co-firing in existing European coal plants. However, unlike Berggren et al. (2008) for Poland, the authors do not compare their results with the potential biomass supply, nor do they compute the CO_2 abatements from co-firing.

Our paper extends these previous contributions by estimating the potential biomass demand from both co-firing and dedicated biomass power plants in the EU-27. We compare our results with the potential biomass feedstocks in Europe, as given in the literature. This allows us to shed light on how the biomass market may be impacted by biomass demand from electricity. We also compute the CO_2 abatements associated with the co-firing opportunities in the EU-27. Additionally, we provide an original method that enables us to estimate the marginal cost of co-fired electricity and the biomass and CO_2 breakeven prices for co-firing. These values reflect the economic conditions that make co-firing profitable in different types of coal plants. To the best of our knowledge, no previous work has provided such an analysis. This allows us to discuss potential consequences of biomass demand from electricity in terms of competition among different usages for biomass.

Compared to the previous literature, our contribution is threefold. First, we estimate the potential biomass demand from the existing power plants in the European electricity sector, considering both biomass co-firing in coal plants and dedicated biomass power plants. Second, we match our estimates with the potential biomass supply in Europe, and we compute the CO_2 abatements associated with co-firing opportunities in the EU-27. Third, we provide a method that enables us to compute the biomass and CO_2 breakeven prices for co-firing.

The remainder of the paper is organized as follows. In Section 2, we give a brief overview of questions related to biomass-based electricity generation and we introduce the methods for estimating potential biomass demand, CO_2 abatements, and breakeven prices for co-firing. Section 3 presents the estimation results. In Section 4, we match our estimates with the potential biomass supply in Europe, and we discuss how the biomass market may be impacted by biomass demand from the European power sector. Section 5 concludes.

2. Material and methods

We begin this section with a brief overview of the technological options for using biomass in power generation. We also describe the impact of some pre-treatments for biomass. Once this background introduced, we present the methods we used in our estimations.

2.1. Technical options for biomass-based electricity

2.1.1. Combustion in dedicated biomass power plants

Dedicated biomass power plants (*i.e.*, power plants that are specifically designed for biomass) have to be adapted to supply limitations. Accordingly, they are typically smaller than coal plants (1–100 MW, about ten times smaller than coal plants), because local feedstocks are limited and transportation costs are high. The small size greatly increases investment costs and lowers conversion efficiency compared to co-firing in coal plants. In Europe, the investment cost of biomass plants varies from USD 3000–5000/KW, depending on technology and size (IEA, 2007). This is about three to ten times more than the investment cost for retrofitting coal plants for co-firing (excluding the indirect co-firing configuration, which is much more expensive). The investment cost may even reach Euros 9000/KW for CHP plants. In this case, the higher investment costs result in higher overall efficiency of the energy conversion chain. Moreover, some countries have adopted specific support policies for biomass when it is used in CHP plants (EURELECTRIC, 2011).

2.1.2. Biomass co-firing in coal-power stations

Co-firing is the simultaneous combustion of biomass and coal in a coal plant. It is the cheapest option for using biomass in electricity. A wide variety of biomass can be used, including herbaceous and woody materials, wet and dry agricultural residues, and energy crops. Currently, the typical conversion efficiency for a dedicated biomass power plant is 25–30% (Ecofys, 2010), while the average efficiency for conventional coal plants is around 36% in OECD countries, with new state-of-the-art plants reaching at least 43% (Wicks and Keay, 2005). Biomass co-firing is expected to reduce the efficiency of coal plants, due to potential sources of losses associated with biomass (*e.g.*, presence of non-preheated air in biomass, increased moisture content, etc). However, the impact is modest for low levels of biomass co-firing (IEA-IRENA, 2013), and conversion efficiency is higher compared with dedicated biomass plants. Accordingly, biomass co-firing is a promising way to convert biomass into electricity, and it offers one of the best opportunities for reducing GHG emissions from electricity. There are three basic co-firing options:

– *Direct co-firing:* This is the cheapest and simplest co-firing configuration. Biomass and coal are burned in the same boiler. This is by far the most widely applied co-firing configuration, and it enables co-firing percentages of approximately 3–5% on

[3] Under Directive 2003/87/EC (establishing the EU ETS and related rules) and Decision 2007/589/EC (establishing guidelines for the monitoring and reporting of greenhouse gas emissions), emissions from burning biomass are exempted from surrendering corresponding allowances. This is equivalent to a zero emission factor applied to biomass.