The effects of scale-up and coal-biomass blending on supercritical coal oxy-combustion power plants

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A R T I C L E   I N F O

Article history:
Received 9 April 2017
Received in revised form 28 January 2018
Accepted 30 January 2018
Available online 3 February 2018

Keywords:
Oxy-combustion
Bio-CCS
Economic analysis
Scale-up
Biomass blends

A B S T R A C T

Carbon Capture and Storage (CCS) with biomass is called to be one of the most important technologies to reduce the climate change all over the world. In addition, supercritical pulverized coal plants have been pointed out as interesting power installations because its high efficiency. In this work, the effects of plants scaling and biomass-coal co-firing level on net present value (NPV), cost of energy (COE) and cost of CO₂ avoided (CCA) have been studied on a supercritical pulverized combusting coal/biomass blends. Aspen Plus® was used to implement technical simulations. Finally, the main factors affecting plants viability were identified by a sensitivity analysis. The results obtained revealed that the use of biomass reduces the NPV in (−0.23,−1.75) M€/MWe, and increases the COE by (0.007,0.263) M€/MWe. However, plant scaling was found to be a more important factor, by reaching an impact of 4.32 M€/MWe on NPV variation in best case. The reduction of oxy-plants viability by biomass using as raw material could be compensated by an increasing of the designed scale-up. Finally, 300 MWe power plants with 40–50% biomass co-firing level were identified as a compromise solution between economy and risk, improving in this way the interest for potential investment.

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1. Introduction

In the new global economy, climate change has become a central issue for the international community. It is becoming increasingly difficult to ignore the important role of the connection between the science community, party and non-party stakeholders to benefit the intergovernmental process and Paris Agreement implementation. In order to improve this work, the last Earth Information Day was organised by the UNFCCC and celebrated in Casablanca on last November. In that conference, 2015 was presented as the warmest year, over 1 °C higher than pre-industrial period [1] by the WMO. According with this finding, the concentration of long-lived greenhouse gases continues to increase, reaching in 2015 the world mean value of 400 ppm (CO₂), 1845 ppb (CH₄) and 328 ppb (N₂O). A considerable amount of literature has been published on the consequences of this situation, such as a record warming at ocean surface and subsurface, the rising on sea levels or more irregular precipitations (very dry in some places and wet in others) [1,2]. In addition, high impact extremes have been attributed to the climate change: 7800 deaths in the Philippines attributed to Typhoon Haiyan, 2013; 250000 excess deaths attributed to drought and famine in 2011–2012 in the Horn of Africa or 4100 deaths attributed to heatwaves in Pakistan and India in 2015 [2]. The causes of this situation must be identified in order to avoid higher disasters.

Many authors have identified the principal cause with the increasing of energy demand due to the economic development and the population growth. The IEA expects a continuous rising on energy demand of OECD countries from 5500 Mtoe in last 2014 for the next 25 years. In addition, developing countries and regions, such as China, India, South and Central America and the Middle East are expecting to be the main sources of the energy demand increasing in that time. In addition, some geopolitical uncertainties in Middle East countries have stablished increasing concerns about the future oil supply. In Europe, the recent United Kingdom decision about leaving the European Union has no precedents in Europe uncertainties.

In this international context, the European Commission established the Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy...
from renewable sources [3]. All the while, it was published the Decision No 406/2009/EC of the European Parliament and of the Council of 23 April 2009 with the objective of reduce the EU States greenhouse gas releases in a time frame of 10 years, up to 2020. Therefore, a 2011—2020 Renewable Energies Plan was designed by the Spanish Energy Department [4] to increase the energy pool proportion was stablished in 70% rape vs. 30% corn according to the biomass with coal co-firing level on the economic viability of a supercritical oxy-combustion power plant. This study was performed by assessing the NPV, COE and CCA variation for five proposed biomass co-firing levels: 0%, 15%, 25%, 50% and 100%. In addition, these levels were combined with different gross electric energy production: 140 MWe, 300 MWe and 460 MWe. These gross power productions were in accordance with Stanger et al. [13] works when they stated: “oxy power plants with CO2 capture to be built should have capacities in the range of 100—500 MWe (gross)”. The conclusions obtained by the evaluation of the fifteen proposed scenarios added to a growing body of literature on oxy-combustion technology and were considered useful to improve several alternative processes to traditional electric production by only coal combustion.

2. Materials and methods

2.1. Materials

Two raw materials were used in this study: a bituminous coal obtained from the northern located mines of León (Spain) and a lignocellulosic biomass blend used in previous works [14]. The biomass was delivered from the north of Spain. The biomass blend proportion was stablished in 70% rape vs. 30% corn according to best oxy-combustion results (pending publication). It was taken as a field bioreidue. The procedures used in biomass characterisation were described in previous works [10]. However, the same properties values in the bituminous coal case were obtained from the data project of a power plant with the same coal as main feedstock [15].

Table 1 summarised the physical and chemical properties of raw materials used in simulations.

| Table 1: Physical and chemical properties of raw materials used in simulations. |
|-----------------|-----------------|-----------------|
| Material        | Coal            | Biomass         |
| Proximate analysis |                |                 |
| Moisture (%)    | 12.0            | 10.1            |
| Volatile matter (%) | 32.0            | 52.4            |
| Ash (%)         | 25.5            | 14.4            |
| Fixed carbon (%) | 30.5            | 23.1            |
| Ultimate analysis                  |                 |
| C (%)           | 65.1            | 57.3            |
| H (%)           | 2.9             | 4.6             |
| N (%)           | 1.4             | 0.8             |
| S (%)           | 1.9             | 1.0             |
| O (%)           | 28.7            | 36.3            |
| Calorific value |                 |                 |
| HHV (MJ/kg)     | 25.08           | 19.18           |
| Properties      |                 |                 |
| Grindability index | 50              | 27              |
| Dielectric constant | 5.0             | 2.5             |

HHV = high heating value,

* Dry basis,

b Dry ash free basis,

c Calculated by difference.
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