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Research paper

Possibilities for CO_2 emission reduction using biomass in European integrated steel plants

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ABSTRACT

Iron and steel plants producing steel via the blast furnace-basic oxygen furnace (BF-BOF) route constitute among the largest single point CO_2 emitters within the European Union (EU). As the iron ore reduction process in the blast furnace is fully dependent on carbon mainly supplied by coal and coke, bioenergy is the only renewable that presents a possibility for their partial substitution. Using the BeWhere model, this work optimised the mobilization and use of biomass resources within the EU in order to identify the opportunities that bioenergy can bring to the 30 operating BF-BOF plants.

The results demonstrate competition for the available biomass resources within existing industries and economically unappealing prices of the bio-based fuels. A carbon dioxide price of 60 € t^{-1} is required to substitute 20% of the CO_2 emissions from the fossil fuels use, while a price of 140 € t^{-1} is needed to reach the maximum potential of 42%. The possibility to use organic wastes to produce hydrochar would not enhance the maximum emission reduction potential, but it would broaden the available feedstock during the low levels of substitution.

The scope for bioenergy integration is different for each plant and so consideration of its deployment should be treated individually. Therefore, the EU-ETS (Emission Trading System) may not be the best policy tool for bioenergy as an emission reduction strategy for the iron and steel industry, as it does not differentiate between the opportunities across the different steel plants and creates additional costs for the already struggling European steel industry.

1. Introduction

The European Union (EU) has set climate targets for 2020, 2030 and 2050 to progressively reduce greenhouse gas emissions up to 80%, by increasing the share of renewable energy in the energy mix and improving energy efficiency [1]. These strict targets, however, require decreasing reliance on fossil fuels from all sectors – not only for electricity, heat and transport. For example, around 18% of all coal consumed in the EU, by countries part of the OECD, is used by the industrial sector – and mostly by iron and steel plants using the blast furnace-basic oxygen furnace (BF-BOF) route [2]. Substituting the coal used for the iron ore reduction by renewables is challenging, as the steel production process from raw materials is mainly dependent on the solid carbon that the coal-based fuels provide. Biomass is the only renewable feedstock that can provide such carbon and at the same time could be upgraded to have similar (although not identical) characteristics to fossil fuels [3]. The iron and steel industry is therefore contemplating the viability of the use of biomass [4], from a technical as well as from the resource availability point of view, as European biomass resources are greatly limited, and it would be desirable to avoid the emissions associated with the long-distance transport of biomass.

The present paper undertakes a study that focuses simultaneously on the availability of biomass resources that are also in demand for other applications, their cost and potential environmental benefits, as well as technical restrictions related to fuel switching. Our intent is to identify the extent to which biomass has the potential to meet the needs of the different stakeholders involved, i.e. the decision makers from the iron and steel industry as well as policy makers interested in reducing the fossil fuel use in the sector.

The EU *Best Available Techniques Reference Document for Iron and*

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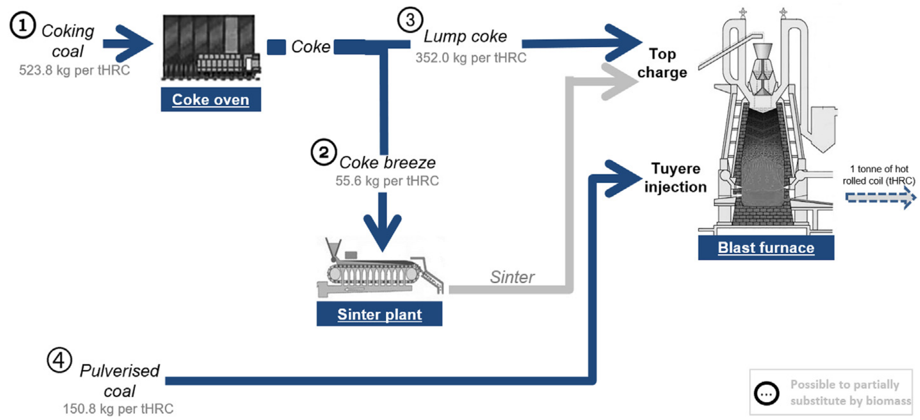

Fig. 1. Coal-based fuel flow during the iron-making stage.

Table 1
Substitution possibilities of coal or coke by bio-based fuels.

Process Unit		Fossil fuel substituted	Heating value ($MJkg^{-1}$) [31]	CO_2 emission factor for fossil fuel ($kg\,kg^{-1}$) [31]	Fuel cost (€ GJ^{-1}) [31]	Possible substitution			
						Charcoal [29]	Wood pellets	Hydrochar	Torrefied fuel
Coke oven	(1)	Coking coal	31.10	2.89	3.98	2-10%	–	–	–
Sinter Plant	(2)	Coke Breeze	29.01	3.23	5.35	50-100%	–	–	–
Blast furnace	(3)	Top charged nut coke	29.01	3.23	5.35	50-100%	–	–	–
	(4)	Pulverised coal	33.37	3.19	3.17	0-100%	20% [21]	25% [18]	22.8% [21]

Steel Production [5] has already suggested that biomass integration for European steelmaking "should be seriously considered", but only when its sustainable sourcing is ensured. The European project called Ultra-Low CO_2 Steelmaking (ULCOS) [6] has focused on the compatibility of bio-based reducing agents with conventional as well as emerging iron and steel making technologies, such as HISARNA or ULCORED [7]. The different properties of biomass to fossil fuels (such as mechanical strength, reactivity, chemical composition and heating value) would allow only partial substitution of coal used across the ironmaking process of the BF-BOF route [8]. However, pre-processed biomass, for example in the form of charcoal, could still offset up to 57% of the CO_2 emissions occurring on-site [9], which would be a significant reduction of national emissions for any country that has an operating BF-BOF steel plant.

The most appealing biomass pre-treatment for iron and steel making, from the technical point of view, is by slow pyrolysis, as the resulting charcoal can have properties close to the conventional coal [10]. Certain plants in Brazil are already fully operating with charcoal in small blast furnaces [11], but as European blast furnaces are generally larger in size (both in diameter and height), stricter requirements on fuel properties take place and charcoal therefore presents opportunities only for partial substitution. Other bio-based products (e.g. wood pellets) could also contain sufficiently high carbon content [12], but their characteristics present even lower fossil fuel substitution possibilities than charcoal [13]. On the other hand, those bio-based products might present better bioenergy opportunities for European steel industry from the biomass availability, cost and supply aspect.

The biomass availability and its sustainable sourcing for the European iron and steel making has been among the main arguments against the technology progression [14]. Currently, 800 kt of charcoal is yearly consumed in Europe, primarily by the barbecue market, where 70% is already imported mainly from Africa [15]. Substituting 5% of the fossil fuels used by even a small European size BF-BOF plant of a production output of 3 million tonnes of crude steel per year would require roughly 120 kt of charcoal (assuming 1:1 substitution of coal by charcoal, where 0.8 t of coal is used to produce 1 t of crude steel [16]). This raises questions about the sufficiency of EU resources for deployment of this solution. On the other hand, the enhanced forest management within the EU and commercial forest growth being around 36% bigger than current EU sourced wood consumption [17] might be able to supply the possible new demand from this industry. Additionally, even though charcoal is the most common form of biomass studied for the iron and steel industry, other progressing technologies are showing potential to create sufficiently high quality and suitable fuel from alternative feedstock, such as organic wastes or agricultural residues. Those include hydrothermal carbonisation (HTC) [18] and torrefaction [19], which are currently in pilot scale forms.

Studies on biomass availability for integrated steel plants have already been done for Finland [20], Sweden [21] and France [8]. The findings indicate that sufficient amount of biomass for their iron and steel plants could be supplied using their national resources, even though competition from other industries will take place. The high cost of the biomass product was identified as the most significant drawback, where the current CO_2 allowance prices do not make the solution economically feasible. However, steel production from those three countries accounts for only 15% of the EU-28 steel produced via BF-BOF route [22]. As the EU Emission Trading System (EU-ETS) [23], aiming to lower the overall emission in large-scale facilities by 21% by 2020 in comparison to 2005 levels, is imposed on the integrated steel plants across the whole Europe, evaluation of biomass availability for other European plants should also be done. The European steel industry is currently missing the comparison of available resources for different plants, together with different upgrading technologies. Without this comparison, strategic use of the limited biomass resources, whilst maximising the environmental benefit, is hard to achieve. In addition, the policy tools imposed with motivation to achieve certain environmental targets might not be effective.

The current work aims to enhance the understanding of the viability