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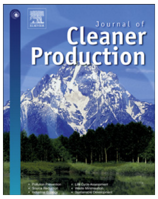

The impact of climate targets on future steel production – an analysis based on a global energy system model[☆]

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ABSTRACT

This paper addresses how a global climate target may influence iron and steel production technology deployment and scrap use. A global energy system model, ETSAP-TIAM, was used and a Scrap Availability Assessment Model (SAAM) was developed to analyse the relation between steel demand, recycling and the availability of scrap and their implications for steel production technology choices. Steel production using recycled materials has a continuous growth and is likely to be a major route for steel production in the long run. However, as the global average of in-use steel stock increases up to the current average stock of the industrialised economies, global steel demand keeps growing and stagnates only after 2050. Due to high steel demand levels and scarcity of scrap, more than 50% of the steel production in 2050 will still have to come from virgin materials. Hydrogen-based steel production could become a major technology option for production from virgin materials, particularly in a scenario where Carbon Capture and Storage (CCS) is not available. Imposing a binding climate target will shift the crude steel price to approximately 500 USD per tonne in the year 2050, provided that CCS is available. However, the increased prices are induced by CO_2 prices rather than inflated production costs. It is concluded that a global climate target is not likely to influence the use of scrap, whereas it shall have an impact on the price of scrap. Finally, the results indicate that energy efficiency improvements of current processes will only be sufficient to meet the climate target in combination with CCS. New innovative techniques with lower climate impact will be vital for mitigating climate change.

1. Introduction

Iron and steel production is one of the major sources of anthropogenic CO_2 emissions. In the EU, the sector is responsible for 4.7% of the total emissions, which amounts to a total of 182 million tonnes of CO_2 (UNFCCC, 2012). The climate change externality has recently been included in the cost structure of products produced within the EU through the EU Emission Trading System (EU ETS). This has led to discussions between industry organisations and policy-makers whether the EU climate policy is negatively affecting the competitiveness of European industries or not (Gielen and Moriguchi, 2003, 2002a, 2002b; Okereke and McDaniels, 2012).

Furthermore, ETS schemes have recently been established in several regions of the world, such as Australia, the EU, Kazakhstan, New Zealand and Switzerland as well as in Québec in Canada and California, Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont in the United States. Several other countries are considering implementation of an ETS and others have already scheduled implementation (International Carbon Action Partnership, 2013). There is already an agreement aimed at linking the EU ETS and the Australian ETS, which is a step towards an international CO_2 price (European Commission, 2013).

This paper addresses the influence that global climate targets may have on future technology choices for iron and steel production, particularly highlighting steel demand patterns and scrap availability. The global climate targets required for mitigating climate change are represented by a binding target limiting radiative forcing in the model, which corresponds to stabilization of the global mean temperature increase between 2.4 and 3.2 °C (Barker

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[☆] The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

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et al., 2007). The global energy system model ETSAP-TIAM was enhanced with explicit iron and steel production technology detail. The model was used to find cost-efficient technology pathways under radiative forcing constraints. In addition, ETSAP-TIAM was coupled with SAAM, a model developed to assess the global availability of scrap. This approach takes the iron ore resources and scrap availability into account, which enables discussions on accumulation of in-use steel in society and implications for future technology choices. Scenarios highlight the impact of future steel demand patterns, a binding global climate target, and no future CCS availability. Essentially, the study addresses the question: *how may a binding global climate target influence future iron and steel technology deployment and scrap use?*

The next section presents the methodology of the paper, including the current and future technology trends in the iron and steel sector. Model results are presented and discussed in the subsequent sections. The main conclusions drawn from the study are then presented, including a discussion on the policy implications of the results. Details on the steel technology deployment are given in Appendix A and details on the new steel technology representation in ETSAP-TIAM are given in Appendix B.

2. Methodology

Traditionally, iron and steel production has been divided into two production routes. The primary route uses iron ore as ferrous resource. These technologies are characterized by high energy demand per tonne of steel produced (see Table 1). Reduction of iron ore to iron, which is done in a blast furnace (BF), requires large amounts of coal as reduction agent. Together with the high temperatures required, it results in the high energy demand of the process. The iron is then refined into steel in a basic oxygen furnace (BOF) or the more energy intensive open hearth furnace (OHF), which is only used to small extent today. Some of the primary production technologies use a limited amount of scrap to supplement the iron ore. There are also some direct reduction (DR) technologies in use, also referred to as solid state reduction, in which iron ore is reduced to steel or other iron products directly. Traditional primary production technologies result in high CO_2 emissions (see Table 1), but research and development in the sector aims at reducing emissions by optimizing current processes and developing innovative approaches (Silveira et al., 2012).

The secondary production route uses steel scrap as ferrous resource and is less energy intensive than the primary route. Scrap is refined into steel using an electric arc furnace (EAF). Steel production based on scrap is less energy intensive since the scrap resource has already gone through the reduction process during its previous life cycle (see Table 1). The secondary route could theoretically be close to CO_2 emission free using current technology since it uses electricity as its main source of energy (see the lower boundary of the Scrap/EAF route in Table 1) (Silveira et al., 2012).

Table 1
Energy and CO_2 emission intensities of steel production processes (International Energy Agency, 2007; World Steel Association, 2008). The range in energy demand depends on the technology used and the aimed steel product (World Steel Association, 2008). The specific CO_2 emissions are country averages for the various routes and the ranges account for the difference in CO_2 emissions for CO_2-free versus coal-based electricity generation (International Energy Agency, 2007).

Processes	Specific energy consumption [GJ/tonne steel]	Specfic CO_2 emissions [tonne CO_2/tonne steel]
Primary Route – BF/BOF	19.8–31.2	
- Advanced BF		1.3–1.6
- Present Average BF		1.5–1.8
Primary Route – BF/OHF	26.4–41.6	
Primary Route – DR/EAF	28.3–30.9	
- Coal-based		2.3–3.0
- Natural Gas-based		0.7–1.2
Secondary Route – Scrap/EAF	9.1–12.5	0.3–0.5

Between the late 1990s and 2012, total steel scrap use increased approximately 60%, from 350 million tonnes to more than 550 million tonnes. Crude steel production increased by 90% in the same period (Bureau of International Recycling, 2013, 2010; International Iron and Steel Institute, 2000). Despite the relatively slow growth of scrap-based steel in the past decades, the structural shift towards increased share of secondary production of steel offers a plausible pathway for reducing the CO_2 emissions from steel production in the long run. However, as shown in previous studies, scrap availability is limited by the historic production and the time lag of its use in society (Davis et al., 2007; Grosse, 2010; Müller et al., 2011, 2006; Pauliuk et al., 2013). Grosse (2010) shows that recycling is not enough to meet the future demand for steel products at the current growth rate of consumption, concluding that policies for increasing sustainable development cannot solely rely on recycling.

In addition to recycling, other solutions exist to reduce the CO_2 emissions from steel production, including new and innovative processes for primary production of steel. The European Ultra-Low CO_2 Steel making (ULCOS) initiative aims at reducing CO_2 emissions from steel production technologies by 50% compared to current best practice. Three groups of options, at different stages of development, are considered within this initiative: (i) carbon capture and storage (CCS) embedded in current steel production technologies; (ii) decarbonised steel production using hydrogen or electrolysis in the reduction process (e.g. the MIDREX process can use synthetic gas containing approx. 70% pure hydrogen as reduction agent), and (iii) use of biomass as reduction agent (potentially together with CCS). These processes have high potential to reduce emissions, but their implementation will require significant investments, which are not foreseen in the short-term (Gojić and Kožuh, 2006; Birat, 2009; Birat et al., 2008; Elliot and Kopfle, 2009). In fact, the technologies proposed will most likely require political incentives to become economically viable. Moya and Pardo (2013) confirm this by showing that major CO_2 emission reductions in the steel industry would only be viable with long payback periods. Climate policy could introduce a cost for CO_2 emissions and potentially influence the cost-efficiency of certain technologies.

Several top-down studies have used regression analysis and econometric models to analyse future trends in the steel sector. Yellishetty et al. (2010) used regression analysis based on previous trends to predict the future production of steel using current technology options. Also the future energy intensity of production was estimated using regression. Lutz et al. (2005) enhance the econometric and environmental model Panta Rhei adding details on steel production technology to analyse future technology change in the German steel industry. Schumacher and Sands (2007) identify the lack of technology detail in computable general equilibrium (CGE) models, which are commonly used for macroeconomic analyses, and enhance the approach with cost-functions to represent the two main production routes. Boyd and Karlson (1993) show a correlation between past technology choice trends in United States' steel industry and energy prices, also using regression analysis. However, the approaches used in the studies mentioned are limited to simulating the current production routes and do not capture innovation in the form of new technologies that can substitute these processes. Furthermore, regression analysis only forecasts the future based on past trends rather than optimizing production to meet a specific objective.

A recent bottom-up study by Pardo and Moya (2013) provides an extensive review of the current best-practice and innovative technologies for steel production in the EU, resulting from cost-benefit analyses for future technology choices. The model is based on