Renewable and Sustainable Energy Reviews 33 (2014) 645–658

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Alternative emerging ironmaking technologies for energy-efficiency and carbon dioxide emissions reduction: A technical review

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ARTICLE INFO

Article history:
Received 28 January 2013
Received in revised form
4 February 2014
Accepted 22 February 2014
Available online 15 March 2014

Keywords:
Ironmaking
Emerging technology
Energy-efficiency
CO_2 emission-reduction
Research and development

ABSTRACT

Iron and steel manufacturing is among the most energy-intensive industries. Ironmaking accounts for the major share of total energy use in steel production in integrated steel mills that use blast furnaces and basic oxygen furnace. Although studies from around the world have identified a wide range of energy-efficiency technologies applicable to the ironmaking process that have already been commercialized, information is limited and/or scattered regarding alternative emerging or advanced energy-efficiency and low-carbon technologies that are not yet fully commercialized. This paper consolidates available information on 12 alternative emerging ironmaking technologies, with the intent of providing a well-structured database of information on these technologies for engineers, researchers, investors, steel companies, policy makers, and other interested parties. For each technology included, we provide information on energy savings and environmental and other benefits, costs, and commercialization status. All the alternative emerging ironmaking technologies eliminate energy-intensive coke production. COREX® Process, FINEX® Process, and Coal-Based HYL Process are very promising alternative emerging ironmaking technologies because they are already commercialized, but they have very low adoption rate in the steel industry worldwide.

Published by Elsevier Ltd.

Contents

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http://dx.doi.org/10.1016/j.rser.2014.02.031
1364-0321 Published by Elsevier Ltd.

1. Introduction

Iron and steel manufacturing is one of the most energy-intensive industries worldwide. In addition, use of coal as the primary fuel for iron and steel production means that iron and steel production has among the highest carbon dioxide (CO_2) emissions of any industry. According to the International Energy Agency (IEA), the iron and steel industry accounts for the largest share – approximately 27 percent – of CO_2 emissions from the global manufacturing sector [1].

Annual world steel demand is expected to grow from approximately 1410 million tonnes (Mt) of crude steel in 2010 [2] to approximately 2200 Mt in 2050 [3]. The bulk of this growth will take place in China, India, and other developing countries in Asia (Fig. 1). This significant increase in steel consumption and production will drive a significant increase in the industry's absolute energy use and CO_2 emissions.

Studies have documented the potential for the worldwide iron and steel industry to save energy by adopting commercially available energy-efficiency technologies and measures [1,4–5]. However, in view of the projected continuing increase in absolute steel production, future reductions (e.g., by 2030 or 2050) in absolute energy use and CO_2 emissions will require innovation beyond technologies that are available today. New developments will likely include alternative ironmaking processes that can economically reduce energy use and CO_2 emissions. Deployment of these new technologies in the market will be critical to the industry's climate change mitigation strategies for the mid and long term. It should be noted that the ttechnology adoption in regions around the world is driven by economic viability, raw materials availability, energy type used and energy cost as well as regulatory regime.

Many studies from around the world have identified sector-specific [6–10] and cross-cutting [11] energy-efficiency technologies for the iron and steel industry that are already commercially available. However, information is limited and not easily accessible regarding emerging or advanced energy-efficiency and low-carbon technologies for the industry that have not yet been commercialized. Since ironmaking consumes highest share of the energy in the steel production from iron ore, this paper consolidates the available information on alternative emerging ironmaking technologies to assist engineers, researchers, investors, iron and steel companies, policy makers, and other interested parties. The paper aims to contribute to energy efficiency, CO_2 and other air pollutants emissions reduction and sustainability in the steel industry by filling the gap in the information.

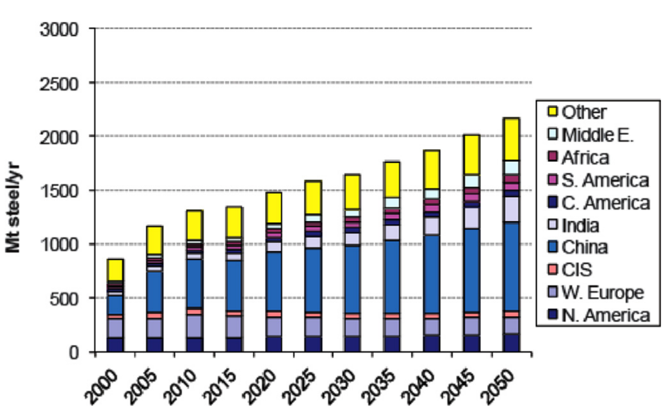

Fig. 1. World steel consumption by region [3].

The information presented in this paper is collected from publically available sources [1–43] and covers the main alternative emerging ironmaking technologies; however, the list of emerging technologies addressed is not exhaustive.

The paper uses a uniform structure to present information about each of the 12 technologies covered. First, we describe the technology, including background, theory, pros and cons, barriers and challenges, and case studies if available. Next, we present the energy, environmental, and other benefits of the technology as well as cost information if available. For most technologies, we include a block diagram or picture. Finally, we identify the commercialization status of each technology. The commercialization status of each technology is as of the writing of this paper and uses the following categories:

- Research stage: The technology has been studied, but no prototype has been developed.
- Development stage: The technology is being studied in the laboratory, and a prototype has been developed.
- Pilot stage: The technology is being tested at an industrial-scale pilot plant.
- Demonstration stage: The technology is being demonstrated and tested at the industrial scale in more than one plant but has not yet been commercially proven.
- Commercial with very low adoption rate stage: The technology is proven and is being commercialized but has a very small market share.

The purpose of this paper is solely informational. Many emerging technologies are proprietary and/or the manufacturers who are developing a new technology are the primary sources of information about it. Thus, in some cases, we identify a company that is the source of a technology so that readers can obtain more information about the company and product. Because the nature of emerging technologies is continual and often rapid change, the information presented in this paper is also subject to change.

2. Description of iron and steel production

Iron ore is chemically reduced to produce steel by one of these three process routes: blast furnace (BF)/basic oxygen furnace (BOF), smelting reduction, or direct reduction [9]. Steel is also produced by direct melting of scrap in an electric arc furnace (EAF). Each of these processes are briefly explained in the section below.

BF/BOF and EAF production are the most common today. In 2010, BF/BOF production accounted for approximately 65 percent of the steel manufactured worldwide, and EAF production accounted for approximately 30 percent [43]. Iron and steel can be produced at separate facilities or in an integrated steel mill, where the iron ore is reduced into pig iron or DRI (direct reduced iron) and then processed into steel at the same site.