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Assessment of energy efficiency improvement and CO_2 emission reduction potentials in India's cement and iron & steel industries

William R. Morrow III *, Ali Hasanbeigi, Jayant Sathaye, Tengfang Xu

Energy Analysis and Environmental Impacts Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, United States

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A B S T R A C T

India's cement industry accounted for over six percent of the world's annual cement production and its iron and steel industry accounted for nearly five percent of the world's annual steel production in 2010. We analyzed 22 and 25 energy efficiency measures applicable to India's cement and iron and steel industries. A forward looking bottom-up Conservation Supply Curve (CSC) model utilizes forecasted Indian cement and iron and steel demand, current adoption estimates for energy efficiency measures, and a stock roll-over methodology for each industry. From 2010 to 2030 cumulative cost-effective electricity savings are 83 TWh, with an associated 82 Mt CO_2 emissions reduction; and cumulative cost-effective fuel savings are 1029 PJ, with associated CO_2 emission reduction of 97 Mt CO_2 for India's cement industry. In India steel sector, cumulative cost-effective electricity savings are 66 TWh, with an associated 65 Mt CO_2 emissions reduction; and cumulative cost-effective fuel savings are 768 PJ, with associated CO_2 emission reduction of 67 Mt CO_2. The estimates from this study give a comprehensive perspective to the Indian cement and iron and steel industries and policy makers about the energy efficiency potential and its associated costs over the next twenty years.

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1. Introduction

India's cement and iron and steel sectors are both large-scale energy intensive industrial sectors. Although much of the current stock of India's production capacity within these two sectors is relatively new due to most recent national economic growth, significant energy efficiency opportunities exist in India's cement and iron and steel production. This paper seeks to quantify that potential using a methodology built upon the studies on China's cement and iron and steel sectors (Hasanbeigi et al., 2013a; 2013b) and various sectors in the United States (Xu et al., 2013a; 2013b) in recent years.

1.1. Overview of India's cement industry

More than 6% of global cement output was produced in India in 2010 representing the second largest national cement industry in the world following China's (USGS, 2012). The 168 Mt cement production in India in 2010[1] was produced from a total capacity of 221 Mt spread across more than 500 cement plants (IndiaStat, 2012a). India also produced 132 Mt of clinker, the primary material used to make cement. India's cement industry has developed a primarily large-plant-capacity sector with 96 percent of the 2009 installed capacity in the 139 large cement plants (CMA, 2010). This has enabled economies of scale, which combined with India's rapid industry growth, has resulted in one of the most efficient cement sectors in the world. 98 percent of the cement production is produced by rotary dry kilns (IndiaStat, 2012b), which are more efficient than rotary wet or semi-dry kilns. Fig. 1 shows processes-wise production output in recent years. India's cement industry's total fuel energy consumption in 2010 was roughly 700 PJ (IndiaStat, 2012c) and the cements industries total electricity consumption was roughly 14.7 TWh (Krishnan et al., 2012).

1.2. Overview of India's iron and steel industry

India's iron and steel sector is the fourth largest national iron and steel sector following China, Japan, and the United States (WSA, 2011). The 68 Mt of Iron and Steel produced in India in 2010 was produced from a total capacity of 75 Mt (IndiaStat, 2012d). India's iron and steel industry produced 53 Mt in 2006 and consumed roughly 1600 PJ of energy (IEA, 2011), an estimated 17% of which was electricity. India's iron and steel production is dominated by

* Corresponding author. Tel.: +1 (0)11 510 495 2027.
E-mail addresses: wrmorrow@lbl.gov (W.R. Morrow), ahasandeigi@lbl.gov (A. Hasanbeigi), jasathaye@lbl.gov (J. Sathaye), ttxu@lbl.gov (T. Xu).

[1] India data is reported using the Hindu calendar which is March through February. For simplification, the dominant year (March through December) is the year used in this report.

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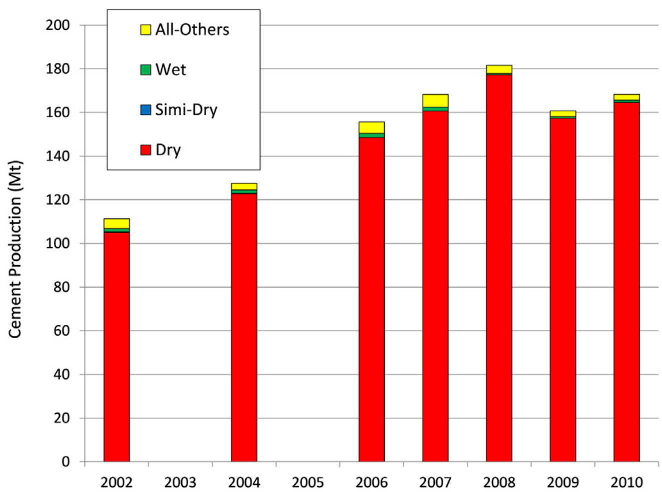

Fig. 1. Indian Cement Production by Kiln Type (IndiaStat, 2012b).

two process routes: blast furnace – basic oxygen furnaces (BF-BOF), and electric arc furnaces (EAF) supplied by either scrap or direct reduced iron (DRI) feedstocks. Fig. 2 shows the capacity share of each (WSA, 2011) with a breakdown of EAF by feedstock (GOI, 2011). Although some natural gas-based DRI capacity operates in India, the relative higher cost of natural gas and limited availability compared to coal has resulted in the dominance of coal-based DRI. This trend is expected to continue because India had relatively abundant domestic coal supplies but imports a significant portion of its natural gas consumption.

2. Methodology

India's economy is expected to expand significantly by 2030, the time frame of this analysis, which will increase India's demand from its cement and iron and steel industrial sectors. By 2030 India's cement industry is anticipated to produce between 646 and 742 Mt cement per year and the iron and steel industry is anticipated to produce between 200 and 242 Mt per year (IEA, 2011). For this analysis, we use the lower growth assumption, but it should be noted that using the higher growth assumption simply increases the benefits, or energy savings potential, in proportion to the relative higher demand to lower demand but does not change the cost effectiveness of measures. See Appendix A for the demand forecasts used in this analysis.

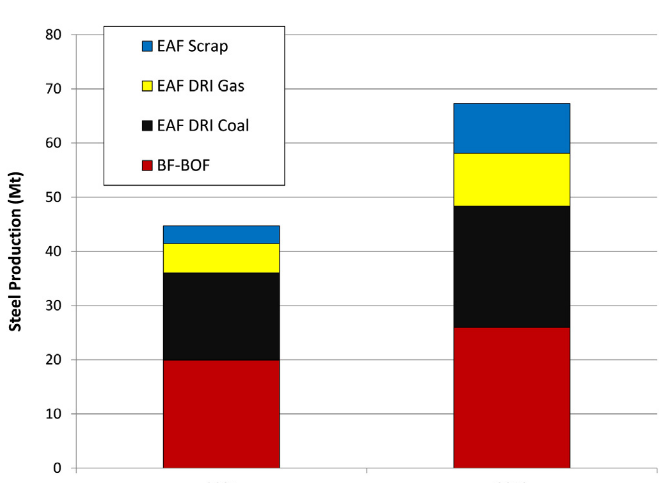

Fig. 2. Indian steel production by process type. Source: WSA, 2011; GOI, 2011.

This paper is unique for India as it provides a detailed analysis of energy efficiency improvement opportunities for the majority of the Indian cement and iron and steel industries. This paper presents an assessment of the potential for energy saving using a technology-level, bottom-up approach and estimates the cost associated with this potential. A "Conservation Supply Curve (CSC)" (Meier, 1982) is used in order to capture the cost-effective potential as well as the technical potential for energy efficiency improvement and CO_2 emission reductions. These results can guide policy makers in designing better sector-specific energy efficiency policy programs.

2.1. Energy efficiency measures and adoption rates

This analysis draws upon work done by Lawrence Berkeley National Laboratory (LBNL) on the assessment of energy efficiency and CO_2 emission reduction potentials of the cement industry in the U.S., where opportunities were identified (Worrell et al., 2000), measures were defined (LBNL & ERI, 2008), and opportunities revised (Worrell et al., 2008); and in China where a modeling methodology was established (Sathaye et al., 2010a, b), and measure penetration rates were estimated (Hasanbeigi et al., 2012) as well as in Thailand where measure penetration rates were also estimated (Hasanbeigi et al., 2010). It also draws upon work done for the iron and steel industry in the U.S. where opportunities were identified (Worrell et al., 1999) and updated (Worrell et al., 2010) and in China where a modeling methodology was established (Sathaye et al., 2010a, b); and energy intensity calculation for Chinese and the U.S. steel industry (Hasanbeigi et al., 2011), as well as assessment of energy efficiency potential in India's cement and iron and steel industries (Morrow et al., 2013a, b). Furthermore, the methodology used for this analysis, i.e. construction of energy conservation supply curves (CSC) and carbon abatement cost curves, is built upon the method developed in recent studies on U.S. industrial sectors that were performed at Berkeley Lab (Xu et al., 2013a, b).

The data on the energy saving, cost, lifetime, and other details on each technology were obtained from these LBNL reports, which are based on case-studies around the world and are assumed to be internationally sourced technologies, as opposed to technologies produced domestically in India. Many of the international energy-efficient technologies examined in LBNL studies are used because other studies on energy efficiency do not provide consistent and comprehensive data on energy savings, CO_2 emission reductions, and the cost of different technologies. Information on some of the technologies examined, however, is presented in other studies (e.g. measures are described for the cement industry (CSI/ECRA, 2009), and the iron and steel industry (APP, 2010), with an update for the iron and steel sector (EIPPCB, 2012)). Additional studies have reviewed the cement industry to identify cost-effective CO_2 emission reduction opportunities at the global level (Benhelal et al., 2013). Others have estimated reduction potentials in the iron and steel sector in the EU's (Moya and Pardo, 2013) and in China's (Zhang et al., 2012). The need to improve both technical efficiency and technological progress has been identified as urgent in India's cement industry (Ray, 2011). In addition to cement production, iron and steel production is an energy intensive industry. This highlights the need for analysis of India's large, energy intensive industrial sectors.

The penetration rates of energy efficient measures in India's current cement and iron and steel industrial sectors is an uncertain but critical variable to the results of the analysis. We have worked closely with Indian industry experts from the CSTEP (Center for Study of Science, Technology, and Policy) to develop high-level estimates for the penetration rates of measures within India's