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A projection for global CO_2 emissions from the industrial sector through 2030 based on activity level and technology changes

Osamu Akashi [a,*], Tatsuya Hanaoka [a], Yuzuru Matsuoka [b], Mikiko Kainuma [a]

[a] Center for Global Environmental Research, National Institute for Environmental Studies, 16-2, Onogawa, Tsukuba, Ibaraki, 305-8506, Japan
[b] Graduate School of Engineering, Kyoto University, Kyoto-Daigaku-Katsura, Nishikyo-ku, Kyoto, 615-8540, Japan

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ABSTRACT

In this study, we simulate global CO_2 emissions and their reduction potentials in the industrial sector up to the year 2030. Future industrial CO_2 emissions depend on changes in both technology and industrial activity. However, earlier bottom-up analyses mainly focused on technology change. In this study, we estimate changes in both technology and industrial activity. We developed a three-part simulation system. The first part is a macro economic model that simulates macro economic indicators, such as GDP and value added by sector. The second part consists of industrial production models that simulate future steel and cement production. The third part is a bottom-up type technology model that estimates future CO_2 emissions. Assuming no changes in technology since 2005, we estimate that global CO_2 emissions in 2030 increase by 15 $GtCO_2$ from 2005 level. This increase is due to growth in industrial production. Introducing technological reduction options within 100 US$/$tCO_2$ provides a reduction potential of 5.3 $GtCO_2$ compared to the case of no technology changes. As a result, even with large technological reduction potential, global industrial CO_2 emissions in 2030 are estimated to be higher as compared to 2005 level because of growth of industrial production.

1. Introduction

In 2004, world energy-related CO_2 emissions were 26.3 $GtCO_2$ [1]. The industrial sector accounted for 37% of this, including indirect emissions from electricity use. Energy-related CO_2 emissions from the industrial sector grew by an average of 1.5%/year between 1971 and 2004, increasing by 1.6 times in about thirty years [2]. It is important to investigate future trends in industrial emissions and their reduction potentials in order to make a plan for low carbon society. The purpose of this study is to estimate industrial CO_2 emissions and their reduction potentials in the mid-term future (up to the year 2030).

Many studies have examined CO_2 emissions from the industrial sector and their reduction potentials. For example, Worrell et al. illustrated reduction cost curve by assessing cost and reduction amount of individual technologies in US steel and cement industries [3,4]. Hanaoka et al. estimated global GHG mission reduction and its cost in 2020 by conducting detailed assessment of abatement technologies and options [5,6]. Oda et al. applied DNE21+ model for world steel and cement industries and analyzed cost effective technologies portfolio in a scenario in which atmospheric CO_2 concentration stabilizes at 550ppm [7]. The International Energy Agency (IEA) assessed future energy technology changes using MARKAL type model and developed CO_2 reduction scenarios towards 2050 [8–10]. The Intergovernmental Panel on Climate Change (IPCC) [2] and Worrell et al. [11] estimated CO_2 reduction potentials in industry sector in 2030. They evaluated CO_2 reductions by assuming baseline based on existing study and compiling reduction rate and cost from various sources of published literature. Hoogwijk et al. estimated reduction potentials based on IPCC's methodology with updated data on baseline scenario [12].

These studies estimate the reduction potentials using a bottom-up approach focusing on technology changes. However, future CO_2 emissions are affected by changes not only in technology but also in industrial activity. Especially for the rapidly developing countries, such as Brazil, Russia, India, and China (BRICs), CO_2 emission estimates are strongly affected by assumptions about industrial production changes. Earlier technology bottom-up studies made exogenous assumptions about those changes and did not provide adequate information about those assumptions, such as the value and the methodology. This study estimates industrial production changes using logically consistent simulation models, and describes the methodology and assumptions in detail.

* Corresponding author. Tel.: +81 29 850 2355; fax: +81 29 850 2422.
E-mail address: akashi.osamu@nies.go.jp (O. Akashi).

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Table 1
Regional Classifications.

Code	Region	Code	Region
JPN	Japan	USA	USA
CHN	China	XE15	EU15 in Western Europe
IND	India	XE10	EU10 in Eastern Europe
IDN	Indonesia	RUS	Russia
KOR	Korea	MEX	Mexico
THA	Thailand	ARG	Argentine
XSE	Other South-east Asia	BRA	Brazil
XSA	Other South Asia	XLM	Other Latin America
XME	Middle East	ZAF	South Africa
AUS	Australia	XAF	Other Africa
NZL	New Zealand	XRW	Rest of World
CAN	Canada		

2. Methodology

2.1. Definitions of regions, sectors and gas

This study splits the world into twenty-three regions, focusing on the major emitting regions and the Asian regions (Table 1).

The target of this study is the entire industrial sector, with special attention paid to two energy-intensive industries, the steel industry and the cement industry. Steel industry account for about 20% of world's industrial energy consumption if energy consumption in coke making process is included [13]. Non-metal minerals industries, which include cement industry, account for 12% of world industries' energy consumption [13] and cement industries account for two-thirds of it [14].

Energy-related and process-related CO_2 emissions are the focus of this study. Energy-related CO_2 includes direct emissions from fossil fuel combustion and indirect emissions from electricity use. It must be noted that CO_2 reductions due to electricity savings are included in reduction in industrial sector while CO_2 reductions due to improvement in emission intensity of electricity production are not. This is because electricity consumption in industrial activity is inside the system boundary of this study while electricity production is out of it. Process-related emissions include emissions from limestone calcination.

2.2. Overview of the simulation system

In general, the amount of CO_2 emissions from industrial sector can be decomposed into three terms, industrial production, energy consumption per unit of industrial production (energy intensity) and CO_2 emissions per unit of energy consumption (carbon intensity) Eq.(1).

$$\text{Emission} = \text{Production} \times \frac{\text{Energy}}{\text{Production}} \times \frac{\text{Emission}}{\text{Energy}} \tag{1}$$

Where, Emission denotes CO_2 emissions, Production represents industrial production and Energy denotes energy consumption.

Earlier bottom-up studies analyze the change in CO_2 emissions by assessing technology and energy-mix change under given amounts of industrial production. That is to say, they are focusing on energy intensity and carbon intensity in Eq.(1). However, CO_2 emissions also depend on amount of industrial production. If production is doubled while other two terms remain constant, CO_2 emissions are doubled. This study considers changes in production, energy intensity and carbon intensity as the drivers of CO_2 emission change and simulates them by using integrated simulation system.

The simulation system consists of three parts (Fig. 1). The first part is a macro economic model, which we call the socio–economic macro model. It simulates macro economic variables, such as GDP and value added by sector. The second part, which we call industrial production models, simulates future steel and cement productions. These models use macro economic variables as inputs, which are estimated using the socio–economic macro model. The third part is a bottom-up type technology selection model. Here we used the AIM/Enduse model [15–17]. The model simulates changes in

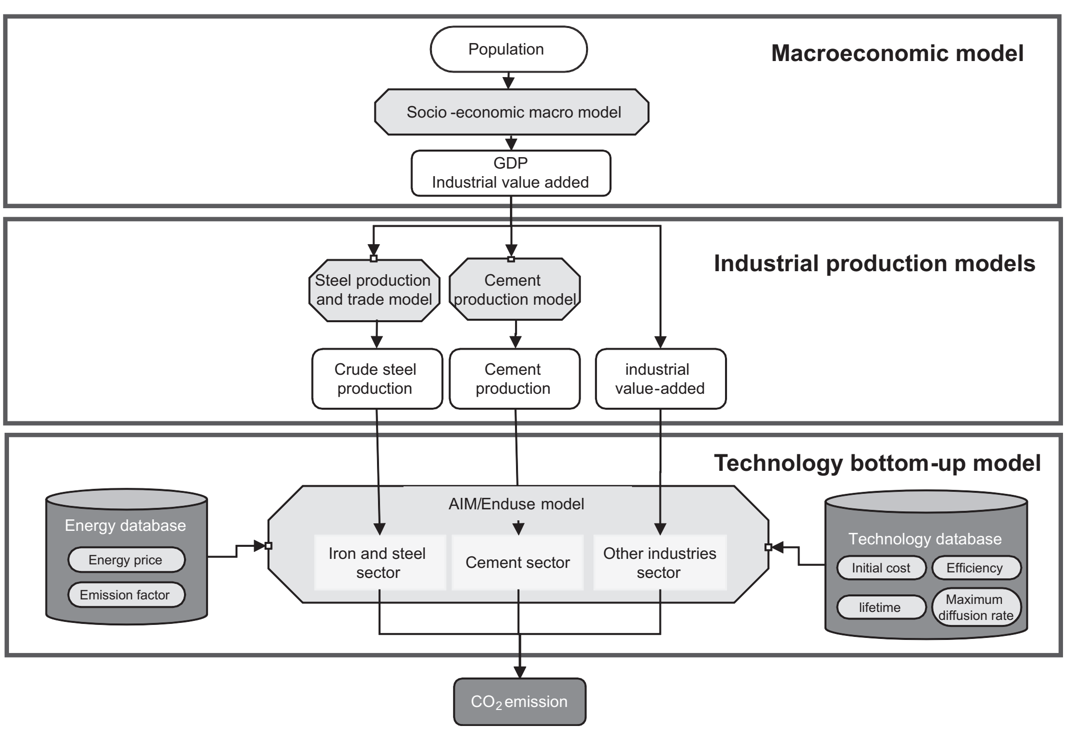

Fig. 1. Structure of the overall simulation system.