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Original Research Article

Assessment of mitigation pathways of GHG emissions from the Korean waste sector through 2050

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ABSTRACT

The waste sector may play a significant role in national mitigation policies with further greenhouse gas (GHG) reduction opportunities mainly because of its linkage to other sectors. However, the waste sector has not drawn much attention from research community mainly because the amount of GHG emissions from the waste sector is notably smaller than other sectors. This study presents emissions estimation and mitigation potentials of the waste sector in Korea. Emission estimates and business-as-usual emissions through 2050 are estimated based on four different treatment methods, including landfill, incineration, wastewater, and biological treatment by considering country-specific emission parameters of wastes, where available. Different types of wastes for each treatment method are investigated to obtain accurate emission estimates. It is expected that GHG emissions in 2050 are about 12.0 Tg CO_2eq, which is 17% less than those in 2010. Mitigation potentials and economic impacts of five different measures are also investigated, and it is revealed that the production of refuse drive fuel from combustible municipal solid wastes may render the greatest benefit with the most mitigation potential of 649 kt CO_2eq. An interdependent nature among mitigation measures is further discussed and it is shown that, if implemented together, the accumulated mitigation potentials are far less than the simple sum of individual potentials. It is implied that an aggregate potential of individual measures needs to be examined when implementing several mitigation measures simultaneously. This study outlines how to investigate emissions estimation and mitigation pathways for the waste sector in a national level.

1. Introduction

It has widely been recognized that a massive consumption of energy and resources in the process of industrialization has caused global climate change which has recently drawn an increasing attention due to its adverse effects on our environment. Actionable international cooperation has long been advocated to cope with global warming since the inception of the Kyoto Protocol of the United Nations Framework Conventions on Climate Change imposing binding obligations on developed countries to reduce greenhouse gas (GHG) emissions. Although some of Annex I countries have taken back their reduction commitment and non-Annex I countries do not carry any obligations to adopt definite targets for carbon emissions, many countries have established a designated national authority to manage their GHG emissions. Further, it has been agreed to establish a legally binding deal comprising all countries by 2015, which was to be effective in 2020, at the 2011 United Nations Climate Change Conference (also referred to as the 17th session of the Conference of the Parties or COP17) held in Durban, South Africa. For example, the Republic of Korea announced its emission target to reduce 30% of business-as-usual (BAU) emissions in 2020. The roadmap to reduce GHG emissions has also been arranged in 2014 [1], and a government-mandated emissions trading has been initiated in 2015. More recently, the Paris Agreement has been negotiated and agreed by the participating 195 countries at the 21st session of the Conference of the Parties held in Paris, France, to reduce emissions and to do their best to keep global warming "to well below 2 degrees Celsius." It is thus expected that more efforts will be made in adaptation and mitigation practices.

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According to the guidelines published by the Intergovernmental Panel on Climate Change (IPCC), GHG emissions are usually to be estimated in various sectors such as energy, transportation, industry, residential and commercial buildings, agriculture and forestry, and waste sectors. Emission estimations by sector are specifically outlined in the IPCC guidelines with the consideration of emission characteristics and data availability in each sector. It is not unusual that the amount of GHG emissions from the waste sector is notably smaller than other sectors. It is noted that GHG emissions from the waste sector has contributed about 2.8% of the total global emissions from anthropogenic sources [2] and a similar trend may be observed in a national perspective. For example, the waste sector in Korea accounts for only 2.2% of national emissions in 2010, which is 14.5 Tg CO_2eq out of 669 Tg CO_2eq. Die to its highly linked with other sectors, the waste sector plays a significant role in national mitigation policies with further GHG reduction opportunities [3].

There have been a vast amount of studies conducted on emissions estimation and mitigation assessment in high-emitting sectors such as energy supply, transportation, residential and commercial buildings. On the other hand, the waste sector has not received much attention from research community mainly due to its low emissions and mitigation potentials. Gielen [4] pioneered the adoption of bottom-up model of Market Allocation (MARKAL) for the assessment of emissions estimation and mitigation potentials in the waste sector. Cosmi et al. [5] and Salvia et al. [6] analysed the effects of mitigation policies on emissions based on MARKAL for certain regional areas in Italy. It should be noted that these studies adopted the mass balance model for estimating GHG emissions from landfill wastes and the most recent IPCC guidelines recommend the use of first-order decay (FOD) model over the mass balance model [7]. More recently, Bakas et al. [8] provided the emissions estimation and mitigation potentials from municipal solid wastes (MSW) for 29 EU countries. Most of the previous relevant studies deal with the GHG emissions from MSW and do not include other types of wastes such as industrial wastes (INW), construction wastes, and hazardous wastes. However, a significant amount of wastes may come from other sources than MSW which signifies the need for including these wastes in the analysis of waste sector. In Korea, for example, the amount of INW is twice more than MSW and the construction and demolition wastes (CDW) account for three times more than MSW. Furthermore, the composition of materials in one type of wastes is significantly different from that in other types. It may thus be desirable to take a holistic approach to assess emissions estimation and mitigation potentials in waste sector by considering different sources of wastes as well as their material compositions. This study aims to provide emissions estimation from waste sector in Korea by taking various sources of wastes (i.e., MSW, INW, and CDW) and their material compositions into consideration as per the guidelines outlined in the IPCC guidelines [7]. In addition, mitigation potentials of five mitigation measures are also analysed to investigate their economic impacts. Even if adapting several measures simultaneously, mitigation potentials of individual measures do not simply add up because of interactions among different measures. Kesicki [9] argued that the analysis of mitigation policies should consider system-wide interactions and time-related aspects of individual measures in a systematic manner. In this regard, an interdependent nature of mitigation potentials is also examined based on the bottom-up analysis. It is demonstrated that variant mitigation pathways may be realized depending upon the order of implementation of individual measures. The remainder of this paper is organized as follows: First presented are data and methodology for deriving the BAU emissions for the Korean waste sector. Emission estimations for different treatment methods are more specifically described. Taking five different mitigation measures into account, mitigation potentials of individual measures are analysed. Interactions among different mitigation measures are further discussed when implementing these measures together. Finally, concluding remarks follow in the last section.

2. Data and methodology

2.1. Waste data

Korea has gone through a rapid economic development since 1970s with the 6th largest GHG emissions in the world (669 Tg CO_2eq yr^{-1}) in 2010. According to the 2010 profile of national GHG emissions of Korea reported by GIR [10], waste sector accounted for about 2.2% of national emissions with 14.5 Tg CO_2eq yr^{-1}. Data used in this study on wastes were obtained from Wastes Disposal and Treatment Yearbook and Report published by the Ministry of Environment [11]. Wastes are divided into five different categories of their sources: MSW, CDW, INW, hazardous wastes, and clinical wastes. Wastes from each category may again be characterized by their material compositions, such as organic, paper, textile, woods, steel, plastics, and so on. Table 1 summarizes the amount of wastes disposed from each source (with proportion in parentheses) in Korea from 1996 to 2010. The total amount of wastes has more than doubled over the period from 62 Mt in 1996 to 135 Mt in 2010. The amount of increasing MSW seems steady at slightly less than 20 Mt yr^{-1}, but its proportion has declined from 30% in 1996 to 13% in 2010. The amount of INW increases to 50 Mt yr^{-1} in 2010 from 35 Mt yr^{-1} in 1996, and its proportion has gradually declined by 20.4%. A remarkable increase is observed for the amount of CDW, which increases more than six times from 10 Mt to over 60 Mt, mainly because of the construction boom over the period. It is noted that the amount of CDW accounts for almost half of the total amount of wastes in 2010. Finally, the combined amount of hazardous and clinical wastes seems negligible in comparison to other waste sources and these two sources will not be considered hereafter.

There are five different treatment methods practiced in Korea such as landfill, incineration, recycling, wastewater, and biological treatment. Table 2 summarizes the amounts of wastes by individual treatment methods, where wastewater and biological treatment are categorized as 'Others' because their amounts are relatively small. It can be observed that the proportion of recycled wastes has risen from 54.5% in 1996 to 82.7% in 2010 while that of landfilled wastes has dramatically declined from 39% in 1996 to 10% in 2010, which may be explained by the introduction of 'volume-rate waste collection program' in 1995. On the other hand, the proportion of incinerated wastes has been steady at an average of 6.0% per year over the period. The amount of wastes for individual treatment methods may also be decomposed by their sources.

2.2. Emission estimation for waste sector

IPCC [7] provides overall procedures of emissions estimation for each waste treatment method. It should be noted that energy generated in the process of waste treatment (so called waste-to-energy, WTE) has not been included in this study as recommended by IPCC guidelines, which states that WTE may be analysed in the energy supply sector. Emissions from the Korean waste sector are estimated according to waste treatment method.

2.2.1. CH_4 emissions from landfill

Emissions estimation for landfilled wastes is one of the most difficult part because landfill gas (LFG) emissions of an inventory year are highly affected by the past activity data. There have been two available methods to estimate LFG emissions: mass balance model and FOD model. However, IPCC Guideline [7] mandates the adoption of FOD model, and mandatory requirements for an