



Where is global waste management heading? An analysis of solid waste sector commitments from nationally-determined contributions



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ABSTRACT

Waste-sector greenhouse gas emissions have long been accepted as a critical component of climate change mitigation efforts because of the significant radiative forcing of methane (CH₄) production from municipal landfills and other emissions from waste management processes. In developed countries, waste generation is expected to peak and decline by the end of the century, whereas waste generation is rapidly rising in many developing nations. The extent to which the countries of the world are planning to handle future quantities of waste has not been explored in detail. This work provides the first detailed account of future waste management planning and waste-sector mitigation strategies through an analysis of stated commitments in the 174 Nationally Determined Contributions (NDCs, documents outlining each country's actions to mitigate carbon emissions and adapt to a changing climate) that have been filed to date within the Framework Convention on Climate Change secretariat in Bonn. One-hundred thirty-seven of 174 countries that submitted NDCs included waste-sector emission mitigation actions, representing approximately 85% of all global emissions. About half (67) of the countries that included waste sector mitigation tactics identified infrastructure or policy actions to meet mitigation commitments, but these strategies vary widely in their scope and level of detail. Landfilling was the most commonly-cited waste-sector commitment (n = 47), followed by deriving energy from waste through various techniques (n = 42). Countries targeting improved solid waste collections had less extensive coverage ($\mu_{\text{collection}} = 38\%$ of generated waste collected) than countries that did not prioritize improved collections ($\mu_{\text{collection}} = 46\%$ of waste generation), but countries not prioritizing the waste sector at all in NDCs had the most limited waste collection coverage ($\mu_{\text{collection}} = 33\%$). Almost all of the countries that specified emissions inventory assumptions (132 of 135) use outdated CH₄ global warming potential values which, coupled with missing or poor waste management data suggests many countries may be underestimating the importance of waste sector emissions in national emissions portfolios. Several examples of data collection and reporting models are identified that can help to inform and potentially improve life-cycle environmental outcomes in the waste sector. Adaptation strategies detailed in NDCs have largely overlooked the waste sector, suggesting inadequate incorporation of future climate scenarios in waste sector infrastructure planning.

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1. Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) adopted a goal in 2015 to limit further global warming to 2 °C above pre-industrial levels as part of the 21st Conference of the Parties (COP 21). COP 21 culminated in the Paris Climate

Agreement, an historic accord that, for the first time, aligned nations toward the common goal of combating climate change and adapting to its impacts (UN Framework Convention on Climate Change, 2015b). To help achieve the stated global warming goal, parties to the Paris Climate Agreement developed Intended Nationally Determined Contributions, referred to as Nationally Determined Contributions (NDCs) following submission. These NDCs tailor broad emission mitigation goals and climate change adaptation plans to the country's specific context by accounting for national priorities, technical and economic capabilities, and relative responsibility for action (Table 1) (World Resources Institute, 2016).

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Table 1
Elements commonly included in country-level NDCs prepared in advance of the Paris Climate Agreement.

NDC element	Description
Introduction and national circumstances	Overview of basic information about the country (population, size, major industries) May include qualitative description of current or historical contribution to climate change and anticipated effects or vulnerabilities of future climate change
Emissions profile	May include historical, current, and/or projected future emissions, presented in aggregate or as the sum of individual climate-forcing pollutants
Mitigation plans and potential	The country's mitigation goals, presented as an anticipated outcome (e.g., a percentage reduction of GHG compared to some baseline), a series of mitigation actions (e.g., GHG-emitting sectors of focus, GHGs of focus), or a combination of the two Targeted sectors commonly include agriculture, buildings, energy efficiency, forestry, renewable energy, transportation, and waste
Adaptation	Establishing the country's need for adaptation and plans to address it
Financing	A discussion of financing plans or other resource mobilization strategies

Greenhouse gas (GHG) emissions from the waste sector represent one of the largest non-CO₂ sources (IPCC, 2013) globally. Although a range of human health environmental consequences can result from waste management (Giusti, 2009; Seadon, 2006), climate-related emissions from waste principally consist of CH₄ emissions from landfills. The magnitude of CH₄ emissions demands action to limit GHG-caused radiative forcing in the short term (Tian et al., 2016). At longer time scales, mitigating waste-sector emissions represents an important “wedge” for stabilizing carbon emissions globally (Pacala and Socolow, 2004) to reduce warming and climate-induced effects such as sea-level rise (Zickfeld et al., 2017).

Increasing population in many countries and accelerated urbanization, particularly in lower- and lower-middle income nations, are expected to increase global waste production for several decades (Hoornweg et al., 2013, 2015). Urbanization may also directly contribute to atmospheric warming (Sun et al., 2016). Additions to building stock and the production or import of materials both have substantial impacts on waste generation, particularly in megacities – those with a population greater than 10 million – which are projected to grow in number from 23 (2010) to 41 by 2030 (United Nations, 2014). While the magnitude of waste production rates in megacities varies depending on the level of infrastructure development and individual consumption, waste production rates in megacities are often far higher than per-capita global averages (Kennedy et al., 2015). Similarly, waste management across the world occurs on a continuum, with disparate challenges spanning financial capacity, technical capacity, and infrastructure. Demographic and economic variables also shape waste quantities and composition, which in turn dictates the technical approaches used to safely handle waste (Barton et al., 2008; Karak et al., 2012; UNEP, 2015).

Previous assessments of global waste management have principally focused on historical management (Karak et al., 2012), current technological practices (UNEP, 2015), or future estimates of waste quantities (World Bank, 2012). The UNFCCC conducted a high-level analysis of NDCs (UNFCCC, 2015b), but the only relevant waste-sector detail indicated the number of countries with a waste-related commitment. Here, the NDCs are examined and the specifics of country-level waste-sector mitigation actions are catalogued and analyzed, representing the first detailed account of how most of the world will be managing waste in the future. This analysis can provide an important baseline against which future updates to NDCs, which are required to occur every five

years under the Paris Climate Agreement's provisions, may be compared. The common formatting structure of NDCs enables a previously-unavailable analytical framework which, coupled with emerging data and measurement systems in the waste sector, can be used to bolster the tracking of waste-sector carbon emission mitigation actions.

2. Materials and methods

2.1. Data from Nationally Determined Contributions

Each nation's NDC was downloaded from the UNFCCC website (UN Framework Convention on Climate Change, 2017) in March 2017. The English-language version of each NDC was reviewed where available, and non-English language NDCs were translated into English prior to review. Each NDC was searched to identify whether mitigation or adaptation plans included the waste sector. Because many countries did not explicitly indicate which commitments were conditional (i.e., commitment contingent on additional funding or resources) or unconditional (i.e., a commitment to be executed independent of outside funding), the commitments were reviewed together.

Waste sector actions were examined by reviewing each NDC and extracting specifically-stated planned actions, such as improving landfilling or diverting organic materials. All specific actions and commitments were extracted and indexed to each country in a spreadsheet program. Each action was tabulated, then five groups were created to reflect the most commonly-cited actions (improved collection, composting, recycling, energy from waste, and improved landfilling).

2.2. Analysis of Country-level waste collection and improvement strategies

Country-level waste collection levels were calculated from previously-published data (Wiedinmyer et al., 2014) as the difference between reported mass of waste generated and mass of waste uncollected (year 2010 values) as shown in Eq. (1).

$$M_{\text{Collected},i} = M_{\text{Generated},i} - M_{\text{Uncollected},i} \quad (1)$$

Here $M_{\text{Collected},i}$ is the mass of waste collected in country i (Mg), $M_{\text{Generated},i}$ is the mass of waste generated collected in country i (Mg), and $M_{\text{Uncollected},i}$ is the mass of waste uncollected in country i (Mg). The waste collection rate (CR) for country i was then computed as shown in Eq. (2).

$$CR_i = \frac{M_{\text{Collected},i}}{M_{\text{Generated},i}} \quad (2)$$

2.3. Country-level non-CO₂ GHG emissions and waste data

Although many NDCs provided an estimate of total GHG emissions, most did not provide sector-by-sector emission estimates. Furthermore, many countries utilized different global warming potential (GWP) values and baseline years in the GHG emission communications – as allowed under NDC development guidelines – which limited direct comparisons. The U.S. Environmental Protection Agency was sourced to establish a consistent baseline for comparison, non-CO₂ emissions data – these data are also presented in the Supplementary Information (U.S. Environmental Protection Agency, 2013). The total non-CO₂ emissions profile and the waste sector emissions were matched with each country with an NDC for further analysis.

In the GWP analysis, the country-GWP match was combined with the waste-sector non-CO₂ emissions data from the

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