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GHG Mitigation and Sustainability Co-benefits of Urban Solid Waste Management Strategies: a Case Study of Ahmedabad, India

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Driven by rising income and urbanization in India, the urban solid waste generation and associated externalities are rising rapidly. Disposal of municipal solid wastes (MSW) in landfills without adequate treatment and segregation is leading to sizable local environmental impacts including land and water contamination, air pollution and emissions of methane which is a potent greenhouse gas. Continuation of the current waste disposal methods shall add to pressure on increasingly scarce land resources in the urban areas. This paper recognises two distinct spatial dimensions of the environmental impacts of urban waste; first, the local impacts which are typically addressed under the urban sustainability programmes and second, and the global climate change impacts from methane emissions which are implemented locally but are driven by the global climate change policies. The paper proposes a framework to integrate solid waste management strategies in cities to mitigate GHG emissions from land-fills and concurrently maximize sustainability co-benefits. Using the case of Ahmedabad, the paper explores three waste management scenarios. i) Business as Usual scenario ii) INDC Scenario follows the commitments as outlined in India's INDC and iii) sustainable low carbon scenario considers the transition towards the more resource efficient economy through implementation of sustainable waste management strategies The scenarios analysis, spanning till the year 2035 is used to identify the potential greenhouse emission reduction and local co- benefits accrue through waste management strategies.

1. Introduction

Increasing incomes and population in recent years has led to rapid changes in consumption patterns in Indian households, especially in urban areas. Trends show a rapid increase in per capita waste generation and total municipal waste generation is expected to increase from 109 kt/d in 2005 to 376 kt/d in 2025, an increase of over three and a half times (Hoornweg and Bhada-Tata, 2012).

Urban solid waste management in India also suffers from operational problems and inefficiency. Inadequate municipal budgets lead to a significant proportion of waste uncollected resulting in disposal in open grounds and vacant plots. A very small number of cities have sanitary landfills while a significant number of cities dispose untreated waste to a large open dumpsite (Unnikrishnan and Singh, 2010). Local governments often face budget and capacity constraints resulting in inadequate and poor waste management practices. Open dumping and burning of MSW without adequate treatment and segregation is leading to significant environmental impacts including land, water and air pollution. Continuation of the existing waste management patterns will exert huge demands on the already constrained land resources in urban areas. In addition to the local environmental impacts of solid waste include water and land pollution, health impacts to residents and impact on air quality, methane emissions from municipal waste are now of increasing concern. In 2010, waste contributed 3 % of the total GHG emissions in India(MoEF, 2010). India's commitment to address climate change is evident in the policies and programs in the past decade. India's National Action Plan on Climate

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Change (NAPCC) was announced in 2008 with the objective of addressing climate change while staying along the sustainable development pathway (GoI, 2008). India's Intended Nationally Determined Contributions (INDCs) communicated to the United Nations Framework Convention on Climate Change (UNFCCC) aims to achieve 33 – 35 % decarbonisation by 2030 outlines reducing emissions from waste as one of the interventions to deliver reductions (UNFCCC, 2015a). The interventions as part of the 'Waste to wealth' conversion in the INDC include enhancing waste to energy facilities, improving supply chains for compost and implementation of scientific landfills . India has proposed a mission on 'Waste to Energy' to its existing National Action Plan on Climate Change. The recent Smart Cities Mission aims to develop 100 cities as Smart cities with a focus on enhancing infrastructure and service delivery. Given the policy announcements and India's INDC target, urban sectors are expected play a major role in achieving these ambitions. Waste management is an important and growing sector contributing to GHG emissions. Previous research in Indian cities has reviewed and assessed the status of MSW management practices Jha et al. 2011; Kalyani & Pandey 2014;); quantified the emissions from municipal solid waste disposal (Talyan et al., 2007). Previous studies have not assessed the impact of different waste management strategies on future GHG emissions at subnational level. Therefore, the paper, assesses to what extent solid waste management strategies in cities can mitigate GHG emissions from land-fills and concurrently maximize sustainability co-benefits using the case study of Ahmedabad.

The paper explores three waste management scenarios, i) Business as Usual (BAU) scenario ii) INDC Scenario and iii) sustainable low carbon scenario. The BAU scenario assumes continuation of existing waste management policies and practices including the actions outlined in India's INDC. The low carbon scenario assumes a more aggressive climate ambition in line with national and global targets and the sustainable low carbon scenario considers the low carbon transition towards a more sustainable approach. The paper has five sections. The second section discusses the waste management scenario in Ahmedabad city. The methodology section describes the scenario outlines and assessment framework used in the paper. The fourth section gives the results from the assessment which are discussed in the conclusion section.

2. Waste Management in Ahmedabad city

With a population of 6.3 million in 2015, Ahmedabad is the seventh largest city in India. The city plays a significant role in the economy of the state of Gujarat and registered a high population growth (3 % CAGR) between 2001 and 2011. Ahmedabad Municipal Corporation provides basic services and infrastructure including solid waste management to the city. The city has a solid waste management department as part of the Municipal Corporation (AMC).

In 2016, 4,400 MT of waste was generated in Ahmedabad with a per capita generation of 700 kg/d (Table-1). As seen in cities in developing countries, organic content has a high share. Barring about 15 % of the waste that is recycled informally, nearly all the waste was earlier disposed off at the 84 ha dumpsite located in the eastern part of the city posing high health risk to citizens. Recently, a new sanitary landfill site has become operational in the city. A 300 MT capacity compost plant was implemented by the AMC on a public private partnership model. An additional 500 MT/d is processed in a waste-to-energy plant, also in public private partnership (PPP) mode.

Table 1: Waste management profile for Ahmedabad city in 2015

Parameter	Value
Waste Generation (t/d)	4,392
Per capita (grams/d)	690
Composition (%)	
Biodegradable	46
Paper	40
Plastics/Rubber	3
Others	13
Inert	34
Collection Efficiency	98%
Treatment/Disposal (t/d)	
Recycling	658
Compost	300
Waste to Pellets	550
Waste to Energy	-
Open Dumping	2,868

3. Methodology

The assessment framework in the paper draws upon recently concluded Paris Agreement under the UNFCCC and the 2030 Agenda for Sustainable Development that includes seventeen Sustainable Development Goals (SDGs) provides broad policy platforms for aligning climate change and sustainable development strategies. The underlying storyline of the scenario drives the assumptions regarding waste management practices including assumptions regarding technology penetration. This was verified through semi-structured interviews with the waste management department at AMC. We then carry out a cost-benefit assessment across the scenarios. The analysis spans the period till the year 2035. For the three scenarios, methane emissions calculations follows the IPCC methodology (IPCC, 2006). The calculation for the capital cost and land footprint area are derived from the estimates of the Planning Commission Government of India (Planning Commission, 2014). This was developed by the Task Force on Waste to Energy constituted to study technological aspects of waste to energy technologies and propose potentially sustainable models of Municipal Solid Waste (MSW) processing including energy recovery through integrated MSW management in the country

3.1 Projections

In future, increase in population growth, rising incomes and change in socio-economic parameters will lead alter the generation and composition of waste. Population and GDP growth projections for Ahmedabad (Pathak and Shukla, 2016) were used to calculate future waste generation projections for the year 2025 and 2035 using logistic regression (Eq(1)-(2)). The asymptotic values for future were based on the level of expected GDP (high-, middle-, or low-income) and per capita waste generation based on that income level. Consistent with global trends, trends in Ahmedabad show a reduction in share of organic waste and increase in proportion of paper, plastic and other combustibles. This trend is expected to continue in future.

$$\text{Generation rate} = \frac{1.5}{1 + \exp -(\text{b} + \text{a} * \text{gdppercapita})} \tag{1}$$

Waste generation (t/y) = generation rate * population * 365 (2)

3.2 Scenarios

3.2.1 BAU Scenario

BAU scenario follows the existing policy interventions at the national and subnational level. Driven by national policies including the recent Municipal waste handling rules (MoEFCC, 2016) as well as the Waste-to-energy mission under India’s National Action Plan on climate change, urban waste management is expected to improve. Similarly, local constraints such as limitations on land available for landfills, will prod the local government to increase efforts to improve waste management. The AMC has recently extended the existing contracts for composting and pelletization. It has also entered into new agreements with private companies for setting up waste processing plants. These includes new capacity for compost, RDF and waste to energy. These are included in the BAU scenario storyline.

3.2.2 INDC Scenario

The INDC highlights waste to energy and composting as key strategies and therefore, the INDC scenario assumes the implementation of these waste initiatives. The INDC scenario differs from BAU in terms of the proportion of waste diverted to waste to energy as well as composting. In the INDC scenario, the local government will pursue more aggressively, waste-recovery options such as energy from waste, composting and improved recovery of useful products with the help of highly advanced technologies. The INDC scenario assumes a more top-down approach to waste management and the focus on decentralized sustainable waste management solutions is lower compared to the sustainable scenario.

3.2.3 Sustainable Low Carbon Scenario

The sustainable low carbon scenario (SLCS) envisions a society where sustainability underpins development. The sustainability paradigm rests on the 3Rs model and is reflected in the society’s attitude to waste generation and management. The sustainable low carbon scenario envisions a future where waste management is driven by a bottom-up initiatives by individual citizens and at the community level. Individual efforts towards sustainable consumption as well as high re-use reduce the per capita waste generation in this scenario. These are complemented by community level initiatives including decentralized composting and recycling. Presently, AMC has implemented 1 t/d compost plants at 2 large public spaces and plans to increase to 10 t/d in the city. Based on the data available for large gardens in seven major zones of the city, 45 ton / d can be composted. The scenario assumes 20 % of the households of the city will compost all their biodegradable waste to compost.

4. Results

Figure 1 shows the generation and break-up of waste management for all three scenarios. Driven by income and population growth, waste generation increases from 690 g/capita in 2015 to 1.5 kg in 2035 resulting in a total waste generation of 17,355 t in BAU and INDC scenario. In the sustainable scenario, increase in re-use of waste at the household level and recycling practices lead to a reduction in waste generation. The waste generation in SLCS is 1,275 t that is 15% lower compared to BAU and INDC scenarios. Processing of waste in BAU increases from 23 % in 2015 to 30 % in 2035 with the implementation of new waste to energy plants, biomethanation and increase in capacity of existing compost plant. The share of recycling however, reduces in BAU. Following the INDC commitment, waste to energy capacity is three times higher in the INDC scenario compared to BAU.

4.1 GHG Emissions

Figure 2 compares the scenarios for methane emissions and capital cost. Methane emissions in BAU increase to over three times between 2015 and 2035. In the INDC scenario, energy and material recovery reduces waste going to the landfill and consequently, methane emissions reduce by 15 % relative to BAU. Re-use, recycling and decentralized composting bring down emissions by 58 % in the SLCS compared to BAU scenario.

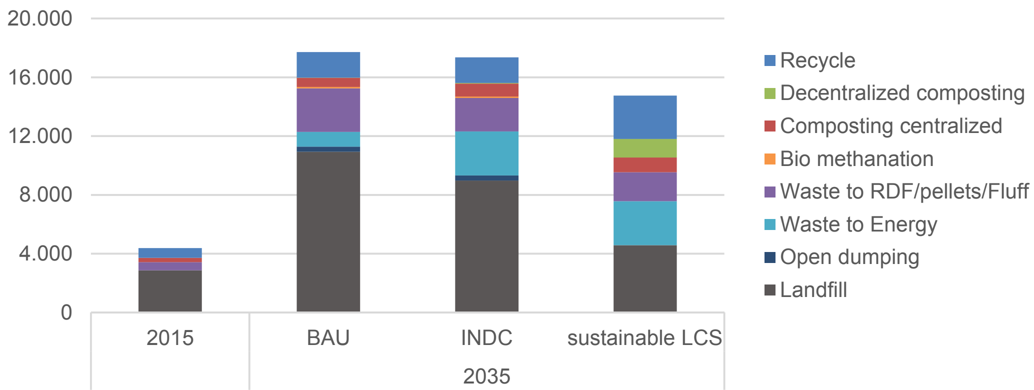

Figure 1: Waste Management

4.2 Capital costs

Levelized capital costs for plant infrastructure and transportation increase in all three scenarios. In BAU, the capital cost increases by five times in 2035 relative to 2015 levels. Costs are even higher in INDC and sustainable low carbon scenario relative to BAU. However, these would be offset from the sale of compost and electricity generated.

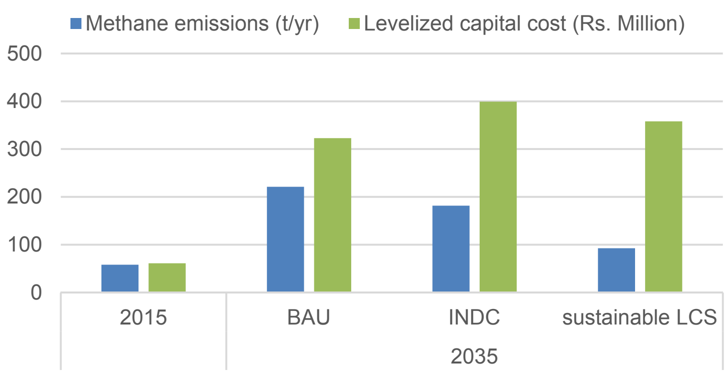

Figure 2: Methane Emissions (t/yr) and capital cost

4.3 Land

Increase in volume of waste requires additional land for processing as well as disposal. The analysis shows that AMC will require an additional 6,100 hectares in 2035 - BAU for setting up new waste processing plants. The INDC scenario requires 14,188 ha in 2035 mainly towards setting up additional capacity for waste to energy and biomethanation (Figure 3). Land requirement in the sustainable low carbon scenario is higher than BAU due to higher capacity of compost and waste to energy capacity. However, it is lower compared to INDC scenario due to lower waste generation and decentralized composting.

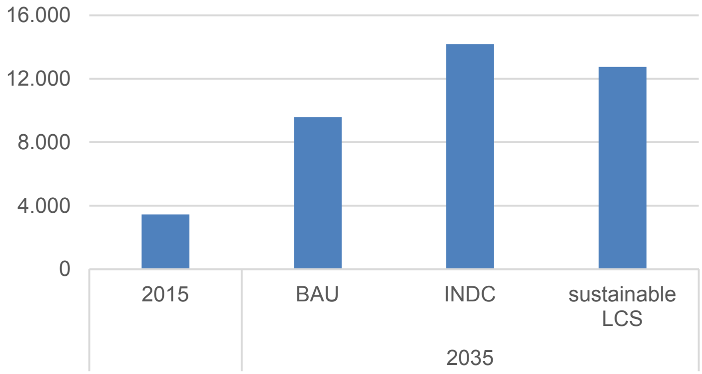

Figure 3: Land requirement (hectares)

5. Conclusions

The Paris Agreement (UNFCCC, 2015b) which was recently accepted by 178 signatories and the UN Sustainable Development Goals (SDGs) highlight the global thrust on aligning sustainable development and climate change. Recent national policies in India, including the INDC commit to address climate change while ensuring sustainable development. India expects to undergo several major transitions in the coming decades in terms of population growth, income and urbanization and consequently a rapid increase in greenhouse gas emissions in cities (Pathak et al., 2015). Urban solid waste management is an important area where the intervention holds significant potential for achieving the twin objectives of emissions mitigation and sustainable development benefits.

Using the case study of Ahmedabad city, the paper assesses future scenarios for urban waste management and how these will have to be adapted to deliver INDCs and the simultaneous mitigation requirements aligned with the global 2 °C temperature stabilization target. The paper explores mitigation contributions from INDC strategies relative to BAU scenario by exploring technological and other options for waste management. Waste to energy technologies are effective options for municipal waste management (Tan et al., 2015) and are commercially viable in several countries (Becidan et al., 2015). For a large country like India, waste to energy can be an effective option for decentralized energy generation in cities and waste management. The focus on waste to energy in India's INDC and the national waste to energy mission are expected to enhance capacity in the near future. This will also entail effective environmental governance approaches to ensure efficient operations and pollution control (Stehlík, 2009). However, the insights from the assessment make a significant case for sustainable waste management solutions including recycling and decentralized composting as important strategies to deliver emission cuts and sustainability benefits. The results from this assessment could be also be useful to develop a roadmap of waste management strategy in order to optimize GHG mitigation benefits and other co-benefits over a longer time-horizon.

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