Annex I: Municipal solid waste potential in cities

Using waste to provide energy is not new. As early as the 19th century, waste incinerators were used to generate mechanical energy or electricity. In absolute numbers, the role of municipal solid waste (MSW) in the energy system is rather modest. In 2013, waste (renewable and non-renewable fractions) accounted for less than 0.4% of total primary energy demand.

For the ETP scenario analysis, the global urban MSW potential available for waste-to-energy (WTE) purposes has been estimated. The estimation comprises the following basic calculation steps:

1. Calculating MSW generation per capita based on urban GDP per capita
2. Calculating the share of generated MSW that is collected. The collection rate is also described as a function of urban per capita GDP
3. Estimating the share of collected waste per capita that is treated in WTE plants
4. Calculating the total MSW potential for WTE by multiplying the collected MSW per capita available for WTE by projected urban population.

Current and future MSW potential to 2050 has been estimated at country level for urban areas, with the calculation steps outlined in the following sections. It is apparent that there are many uncertainties in the outlined calculation steps since data on current MSW generation or collection in many countries are missing and had to be estimated.

In many cases it was not possible to verify which fractions or sources of waste were included in city or country statistics. The definition of MSW in terms of origin or fractions included varies by country and among international organisations. Where possible, the OECD definition of MSW was used. It defines municipal waste as: “waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities” (OECD, 2016).

MSW generation per capita

Urban waste generation per capita is strongly influenced by urban income levels, as shown in Figure I.1 for a collected dataset of around 600 cities. The GDP per capita data for the cities were taken from the McKinsey Global Institute’s Cityscope v2.55 database, which contains GDP data per capita for the year 2012 in USD in purchasing power parity (PPP) terms for around 2 900 cities (McKinsey Global Institute, 2015). MSW generation per capita data are not necessarily for the

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1 This version of the database is not publicly available, but GDP data for more than 2 600 cities for the years 2010 and 2025 are available through the app Urban World (www.mckinsey.com/mgi/overview/in-the-news/urban-world-app).
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year 2012 but for the most recent available years. The individual sources for MSW generation of cities are listed in the section “Data sources for MSW generation” at the end of this annex.

The estimated trendline in Figure I.1 has been used to estimate urban MSW generation per capita as a function of urban GDP per capita. Urban GDP projections at country level have been estimated for the modelling horizon 2013-50 based on data from McKinsey Global Institute (2015), IMF (2015) and IEA (2015).

Figure I.1  Urban MSW generation per capita as a function of urban income levels

Note: Sizes of the bubbles correspond to the cities’ populations in 2012.
Sources: UN DESA (2014), World Urbanisation Prospects: The 2014 Revision; McKinsey (2015), McKinsey Global Institute Cityscope v2.55; for sources for waste generation, see section “Data Sources for MSW generation” at the end of the annex.

Key point: MSW generation per capita is strongly driven by income, with saturation levels being reached at higher income levels.

Combining the urban MSW generation per capita projections obtained in this way with urban population projections based on the United Nations’ World Urbanization Prospects: The 2014 Revision (UN, 2014), total quantities of MSW generated have been estimated (Table I.1).

Table I.1 • Urban waste generation and underlying assumptions by region, 2013 and 2050

<table>
<thead>
<tr>
<th>Region</th>
<th>2013</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban population (millions)</td>
<td>Urban GDP (USD/cap.)</td>
</tr>
<tr>
<td>China</td>
<td>744</td>
<td>18 625</td>
</tr>
<tr>
<td>India</td>
<td>401</td>
<td>9 444</td>
</tr>
<tr>
<td>United States</td>
<td>260</td>
<td>56 399</td>
</tr>
<tr>
<td>European Union</td>
<td>378</td>
<td>39 395</td>
</tr>
<tr>
<td>Africa</td>
<td>423</td>
<td>9 243</td>
</tr>
<tr>
<td>Middle East</td>
<td>152</td>
<td>28 810</td>
</tr>
<tr>
<td>Latin America</td>
<td>363</td>
<td>17 265</td>
</tr>
<tr>
<td>Other OECD</td>
<td>395</td>
<td>32 154</td>
</tr>
<tr>
<td>Other non-OECD</td>
<td>616</td>
<td>17 004</td>
</tr>
<tr>
<td>World</td>
<td>3 732</td>
<td>22 760</td>
</tr>
</tbody>
</table>

Notes: USD are in real USD 2014 and PPP terms; the analysis has been done for 156 countries, but summarised here for major countries or world regions. The 2013 waste generation numbers are estimated numbers, not statistical values, and may therefore deviate slightly from national statistics.
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It is estimated that global urban MSW generation will increase from 1 300 Mt in 2013 to 2 720 Mt in 2050 (Figure I.2). Since GDP and population projections are assumed to be the same in each ETP scenario (6DS, 4DS and 2DS), urban MSW generation is also the same in all three scenarios.

MSW generation in rural areas has been derived using a similar methodology, resulting in an estimated MSW generation in rural areas of 500 Mt in 2013, increasing to around 900 Mt in 2050.

**Figure I.2  Urban MSW generation in ETP scenarios by region**

![Graph showing urban MSW generation in ETP scenarios by region](image)

Source: IEA analysis.

**Key point:** Global urban MSW generation more than doubles between 2013 and 2050.

**Collection rates of generated MSW**

In the same way as waste generation rates, collection rates of waste are strongly influenced by income levels, as shown in Figure I.3 based on national waste collection rates from Hoornweg and Bhada-Tata (2012). The collection rate varies widely by country, from 20% in some African countries to 100% in OECD countries. The data suggest that above a national income level of USD 25 000 per capita, a 100% collection rate can be assumed. Below USD 25 000 per capita a functional relationship has been estimated based on the data shown in Figure I.3.

Taking into account the collection rates, urban collected MSW quantities are estimated at 1 200 Mt in 2013 and 2 650 Mt in 2050. This represents 97% of urban MSW generated in 2050, as most countries have passed the assumed USD 25 000 income threshold by then.
Key point: Collection rates reach 100% at income levels above USD 25 000 per capita.

Share of MSW treated in WTE

WTE is an integral component of waste management strategy, but it is not the only option. Following a broadly accepted waste management hierarchy, measures to avoid waste and to recycle valuable waste fractions are the preferred steps. Only the remainder is combusted in WTE plants. Landfilling is the least preferable option and should be reduced to a minimum because it uses land. If not managed properly, landfilling can also pollute the local environment and contribute to global warming through methane emissions, or so-called landfill gas. However, the impact of the latter can be reduced by recovering the landfill gas and using it for energy purposes.

Many cities in developing and emerging economies are still far from this ideal strategy. Not all waste that is generated is collected, posing health risks. Collected waste is often dumped in open, poorly managed landfills, creating environmental and health risks. In practice, informal waste pickers and recyclers can play an important role in handling the residential waste. In Delhi, 27% of the city’s waste is collected by informal waste pickers (Gupta, 2012).

One can observe some relationship between income levels and the share of MSW treated in WTE plants, but the link is much weaker compared to waste generation and waste collection rates, with higher income levels being a necessary condition but not the sole factor in the uptake of WTE (Figure I.4).

In this analysis, it has been assumed that by 2050 WTE could reach a share of up to 40% of MSW collected, except in countries that already today have a high share, where this share has been assumed to stay constant over the analysis horizon. If no data were available on the current use of WTE, it has been assumed that up to 5% of collected MSW was available for WTE in 2013, increasing linearly to a maximum share of 40% by 2050.

The heating value of MSW can vary from 8 MJ/kg to 20 MJ/kg, depending on the shares of burnable fractions (organic, paper, plastic) in the waste. In this analysis, for simplicity, a uniform lower heating value of 10 MJ/kg has been assumed in all countries and for all time periods.
Urban MSW potential

Based on the outlined assumptions on urban waste generation per capita, share of waste collected, share of waste treated in WTE and the heating value of waste, the urban MSW potential per capita for WTE can be calculated. Multiplying this per capita potential by the assumed urban population projection in a country gives the urban MSW potential available for energy purposes.

Following this approach, the overall global urban MSW potential for WTE has been estimated to be EJ 1.9 in 2013, increasing to EJ 11 in 2050 (Figure I.5). The 2013 potential should not be confused with the actual use of urban MSW for energy purposes of EJ 1.2, but rather represents the potential amount that could have been used under the stated assumptions. The MSW potential for WTE in rural areas has been estimated to be EJ 3.6 in 2050, increasing the total MSW potential to EJ 14.6 in 2050.

As described in the previous section, the share of collected urban MSW available for WTE has been limited to a maximum of 40% in 2050 (except for those countries already having a higher share today). Assuming that all collected MSW would be available for energy purposes increases the urban MSW potential to EJ 12.2 in 2013 and EJ 27.6 in 2050. Including also rural areas, the total MSW potential in urban and rural areas combined increases to EJ 15.8 in 2013 and EJ 36.5 in 2050.
**Key point:** Urban MSW has the potential to provide EJ 11 of primary energy in future, an amount corresponding to the current total primary energy demand of Brazil.

**References**


**Data sources for MSW generation**


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