

Sustainability Assessment of Waste Management System for Mexico City (Mexico) – Based on Analytic Hierarchy Process

Nina Tsydenova ^{1,*}, Alethia Vázquez Morillas² and Arely Areanely Cruz Salas ²

¹ School of Computing Science, Business Administration, Economics, and Law (Faculty II), Carl von Ossietzky University of Oldenburg; 26129 Oldenburg, Germany

² Energy Department, Area of sustainable technologies, Universidad Autónoma Metropolitana UAM—Azcapotzalco; 02200 Mexico City, Mexico; alethia@correo.azc.uam.mx (A.V.M.); areanelyc@gmail.com (A.A.C.S.)

* Correspondence: nina.tsydenova@gmx.de; Tel.: +49-176-973-49877

1 Description of MBT plant Ecoparc 4 (Spain)

Ecoparc 4, in the metropolitan area of Barcelona, is a treatment plant with a total nominal capacity of 300.000 Mg per year, consisting of a capacity of 225.000 Mg per year of residual MSW and 75.000 Mg per year of separately collected organic waste. The plant is treating mainly residual MSW since the start of operation in November 2010. The treatment is based on the classic MBT concept with composting.

Process flow description:

From storage bunkers the waste is fed to three identical lines (30 Mg per hour each), that start with a screening of bulky materials in a trommel of 350x350 mm size. The screened overflow is incorporated in the plant residue, while the underflow enters a manual sorting line where glass, metals are removed. Subsequently, each material flow passes a bag opener and enters a large double section trommel screen (90 mm and 150x250 mm). The screening process generates three streams:

- <90 mm: predominantly organic fraction which is sent to the biological treatment after passing an over magnet for ferrous metals recovery;

- <150x250 mm: consists of mainly recoverable materials, in majority 3D shape objects, and is forwarded to the automatic sorting steps;
- >150x250 mm: consists in majority of 2D objects and is forwarded to automatic sorting steps.

All the streams recovered, and the remaining 3D residuals undergo a manual sorting process. The purity of material streams separated is increased, while additional materials are separated from the 3D residuals. The remaining materials form the main residue stream of the plant, which is sent to an incineration plant.

The fraction < 90 mm sorted out to be organic goes to windrow composting. However, the purity of the result product does not allow the compost to be used as a fertilizer, but it contributes to the volume reduction.

2 Mass flow diagram (MFD) of Baseline Scenario

Figure S1. Mass flow diagram of Baseline Scenario

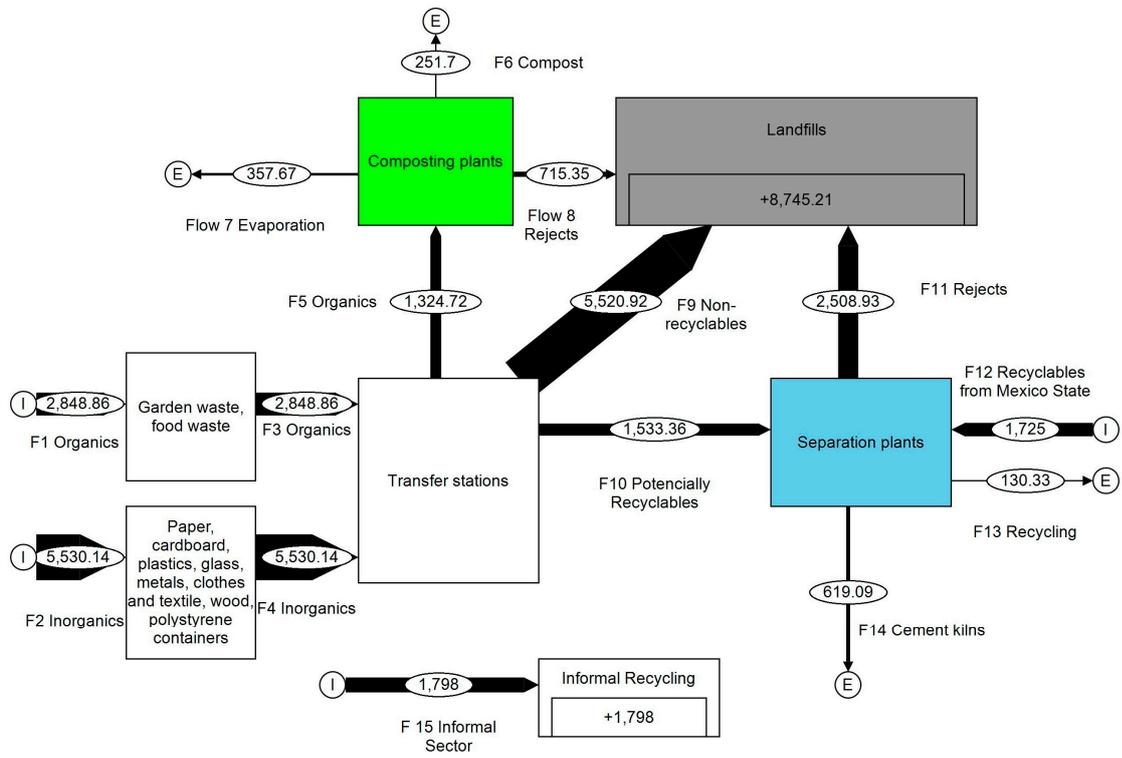


Table S1. Details of the flows of the MFD of Baseline Scenario

Waste flow	Description	Method of estimation	Information source
F1	MSW collected as "organics" by municipal workers	Calculated of 34 % of 8379 Mg of collected waste	Waste generation: SEDEMA (2016)
F2	MSW collected as "inorganics" by municipal workers	Calculated of 66% of 8379 Mg of collected waste	Waste generation: SEDEMA (2016)
F3	"Organics" delivered to the transfer station	Calculated of 34 % of 8379 Mg of collected waste	Waste generation: SEDEMA (2016)
F4	"Inorganics" delivered to the transfer station	Calculated of 66% of 8379 Mg of collected waste	Waste generation: SEDEMA (2016)
F5	Sorted organic fraction of MSW (OFMSW)	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F6	Produced compost ready for sale	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F7	Evaporation (water and volatile solids)	Figure estimated by authors based on Andersen et al (2010)	Estimate by authors based on Andersen et al (2010)
F8	Sorted residues which are not suitable for composting	Calculated by the authors (F5-F6-F7)	Estimate by authors
F9	Inorganic waste not suitable for recycling process	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F10	Recyclable material from the mixed waste (plastics, paper, cardboard, all metals, glass, textile and wood)	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F11	Rejected material from separation plants	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F12	Recyclable material imported from Mexico State	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F13	Sorted material manually at separation plants, which go further to recycling	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F14	Sorted material at separation plants, which is not suitable for recycling, bus is used as RDF at cement kilns	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F15	Collection by informal sector	Figure reported by Gómez Flores and Quintero, 2011	(Gómez Flores and Quintero, 2011)

2 Mass flow diagram (MFD) of AD Scenario

Figure S2. Mass flow diagram of AD Scenario

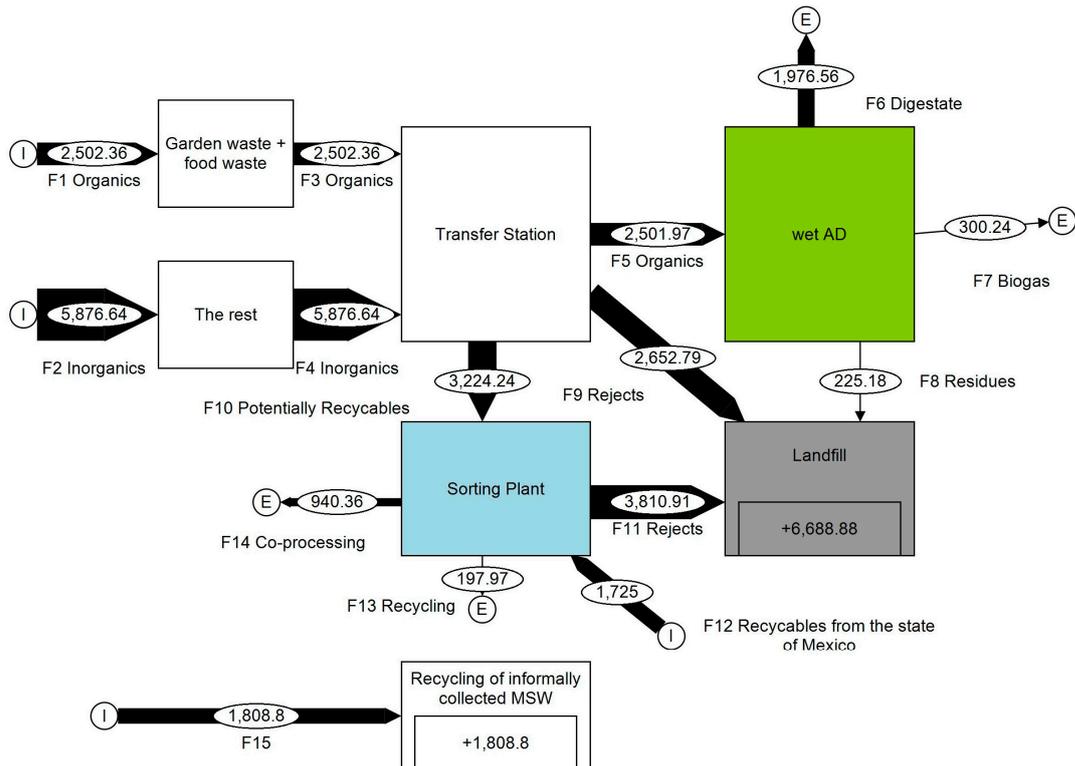


Table S2. Details of the flows of the MFD of AD Scenario

Table S2	Details of the flows of the MFD		
Waste flow	Description	Method of estimation	Information source
F1	MSW collected "organics suitable for AD" by municipal workers (garden waste + vegetable waste)	Calculated of 29.86 % of 8379 Mg of collected waste. 29.86% estimated by authors based on waste composition Figure 1.	Waste generation: SEDEMA (2016); estimate by authors-
F2	MSW collected as "the rest" by municipal workers	Calculated of 70.14% of 8379 Mg of collected waste	Waste generation: SEDEMA (2016); estimate by authors.
F3	"Organics suitable for AD " delivered to the transfer station	Calculated of 29.86 % of 8379 Mg of collected waste.	Waste generation: SEDEMA (2016)
F4	"The rest" delivered to the transfer station	Calculated of 70.14% of 8379 Mg of collected waste	Waste generation: SEDEMA (2016)
F5	Organic fraction of MSW (OFMSW) suitable for AD delivered to the plant	Calculated of 29.86 % of 8379 Mg of collected waste.	Waste generation: SEDEMA (2016); estimate by authors.
F6	Produced digestate	(79% of the input) Figure reported by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)	Estimate by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)
F7	Produced biogas	(12% of the input) Figure reported by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)	Estimate by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)
F8	Sorted residues which are not suitable for AD	Calculated by the authors (F5-F6-F7)	Estimate by authors
F9	Inorganic waste not suitable for recycling process	Calculated by the authors (F3+F4-F5-F10)	Estimate by authors
F10	Recyclable material from the mixed waste (plastics, paper, cardboard, all metals, glass, textile and wood)	Figure reported by SEDEMA (2016)	Estimate by authors
F11	Rejected material from separation plants	Figure reported by SEDEMA (2016)	Estimate by authors
F12	Recyclable material imported from Mexico State	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F13	Sorted material manually at separation plants, which go further to recycling	(4%of the input) Figure reported by SEDEMA (2016)	Estimate by authors
F14	Sorted material at separation plants, which is not suitable for recycling, but is used as RDF at cement kilns	(19% of the input) Figure reported by SEDEMA (2016)	Estimate by authors
F15	Collection by informal sector	(14% of the MSW generated) Figure reported by Gómez Flores and Quintero, 2011	Gómez Flores and Quintero, 2011)

3 Mass flow diagram (MFD) of Mechanical-Biological Treatment (MBT) Scenario

Figure S3. Mass flow diagram of MBT Scenario

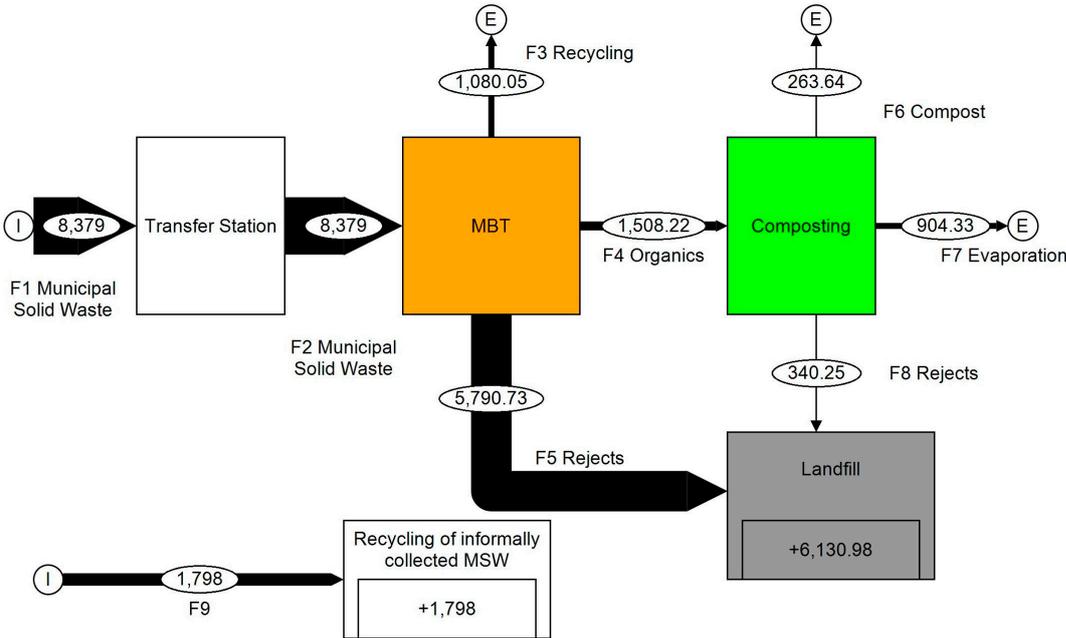


Table S3. Details of the flows of the MFD of MBT Scenario

Waste flow	Description	Method of estimation	Information source
F1	Collected mixed MSW	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F2	Collected mixed MSW delivered to transfer stations	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F3	Sorted (manually and mechanically) recyclables sent to recycling (glass, plastics, paper and cardboard, metals)	Figure reported by Navarotto and Dominguez (2016)	Estimate by authors
F4	Sorted through a trommel particles <90 mm, considered to be organics	Figure reported by Navarotto and Dominguez (2016)	Estimate by authors
F5	Sorted out non-recyclables	Calculated by the authors (F2-F3-F4)	Estimate by authors
F6	Produced compost	Figure reported by Navarotto and Dominguez (2016)	Estimate by authors
F7	Evaporation (water and volatile solids)	Figure reported by Navarotto and Dominguez (2016)	Estimate by authors
F8	Residues to the landfill, which can't be composted	Calculated by the authors (F4-F6-F7)	Estimate by authors
F9	Collection by informal sector	Figure reported by Gómez Flores and Quintero, 2011	(Gómez Flores and Quintero, 2011)

4 Mass flow diagram (MFD) of Incineration Scenario

Figure S4. Mass flow diagram of Incineration Scenario

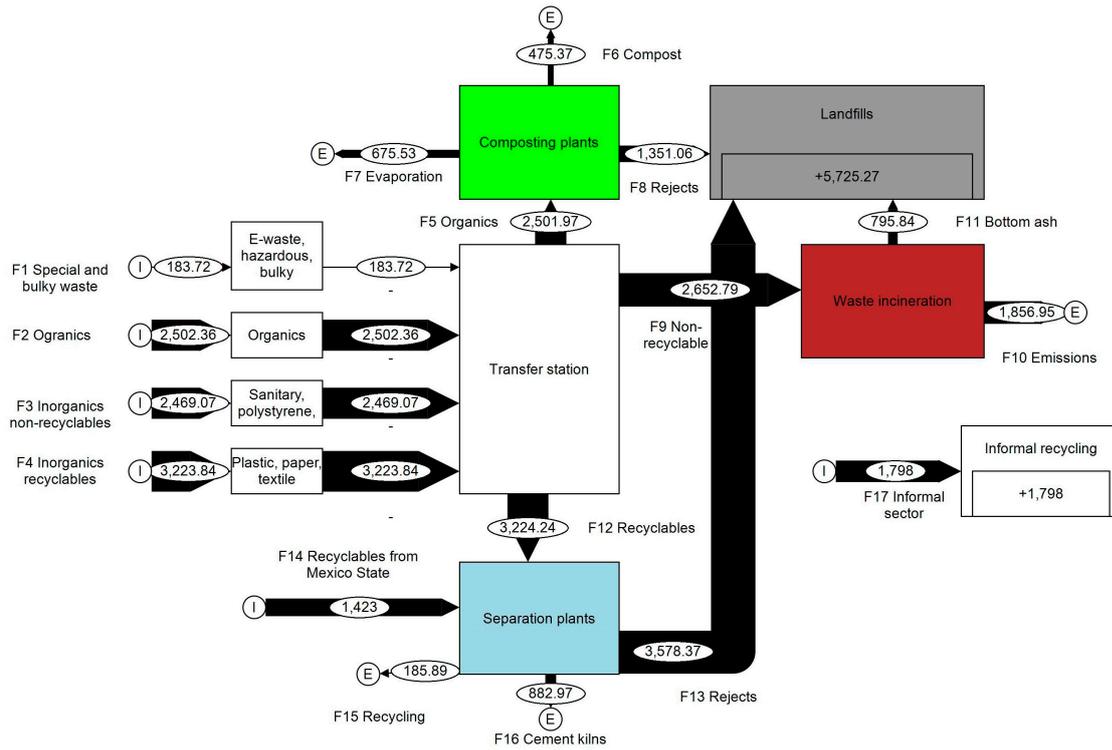


Table S4. Details of the flows of the MFD of incineration Scenario

Waste flow	Description	Method of estimation	Information source
F1	MSW collected as "special and bulky waste" by municipal workers	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F2	MSW collected as "organics" by municipal workers	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F3	MSW collected as "inorganics non-recyclables" by municipal workers	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F4	MSW collected as "inorganics recyclables" by municipal workers	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F5	Sorted organic fraction of MSW (OFMSW)	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F6	Produced compost ready for sale	(19% of the input) Estimated by authors based on SEDEMA (2016)	SEDEMA (2016)
F7	Evaporation (water and volatile solids)	(27% of the input) Figure estimated by authors based on Andersen et al (2010)	Estimate by authors based on Andersen et al (2010)
F8	Residues to the landfill, which can't be composted	Calculated by the authors (F5-F6-F7)	Estimate by authors
F9	Non-recyclables collected separately	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F10	Emissions from waste incineration	(70% of the input) Figure reported by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)	Estimate by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)
F11	Bottom ash from waste incineration	(30% of the input) Figure reported by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)	Estimate by Österreichisches Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015)
F12	Recyclable material collected separately (plastics, paper, cardboard, all metals, glass, textile and wood)	Calculated by the authors based on the MSW composition Tabel 1.	Estimate by authors
F13	Rejected material from separation plants	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F14	Recyclable material imported from Mexico State	Figure reported by SEDEMA (2016)	SEDEMA (2016)
F15	Sorted material manually at separation plants, which go further to recycling	(4% of the input) Figure reported by SEDEMA (2016)	SEDEMA (2016)

F16	Sorted material at separation plants, which is not suitable for recycling, but is used as RDF at cement kilns	(19% of the input) Figure reported by SEDEMA (2016)	SEDEMA (2016)
F17	Collection by informal sector	(14% of MSW generated) Figure reported by Gómez Flores and Quintero, 2011	(Gómez Flores and Quintero, 2011)