

Supplementary Materials

1 Energy Potential Computations

The present section provides a detailed set of reactions that were utilized in estimating the energy potential of each waste management facility.

1.1 Incineration Plants

The energy potential from incinerators is estimated according to the caloric value of different waste compositions, and was computed using the following equation:

$$EP = W_d \times \eta \times \sum(M_i \times CV_i) \quad (1)$$

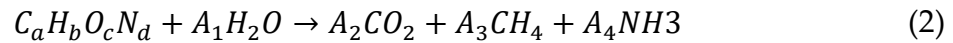
where EP is the energy production (kWh), W_d is the dry weight of treated waste (kg), η is the efficiency conversion within incinerators (30%) [1], M_i is the mass fraction of material i in the waste stream, and CV_i is the calorific value of material i (kWh/kg) (from Table S1).

Table S1: Calorific values of waste fractions [2].

Parameter	Paper	Plastic	Glass	Metal	Food	Textiles	Wood	Others
Calorific value (CV) (Btu/kg)	14991	30865	0	661	5291	17857	16094	11464

1.2 Anaerobic Digestion Plants

Methane generation is used to estimate energy recovery from AD plants. The theoretical methane yield was determined using the stoichiometric equation of anaerobic decomposition using the following equation [3]



$$A_1 = \frac{(4a - b - 2c + 3d)}{4} \quad (3)$$

$$A_2 = \frac{(4a - b + 2c + 3d)}{8} \quad (4)$$

$$A_3 = \frac{(4a - b - 2c - 3d)}{8} \quad (5)$$

$$A_4 = d \quad (6)$$

where A_1 , A_2 , A_3 , A_4 are number of moles of H_2O , C_2O , CH_4 , and NH_3 , respectively, meanwhile a , b , c , and d represent the chemical composition of biodegradables and were obtained from the results of the ultimate analysis. The ultimate analysis of different waste streams for Abu Dhabi was conducted (Table S2).

Table S2: Ultimate analysis of municipal solid waste streams

Material	%C	%H	%O	%N	%S	%Ash
Paper	10.88	1.50	11.0	0.08	0.05	1.50
Plastic	11.40	1.37	4.33	0.00	0.00	1.90
Glass	0.02	0.00	0.02	0.00	0.00	3.96
Metal	0.14	0.02	0.13	0.00	0.00	2.72
Food	18.72	2.50	14.66	1.01	0.16	1.95
Textiles	1.65	0.20	0.94	0.14	0.00	0.07
Wood	1.49	0.18	1.28	0.01	0.00	0.05
Others	1.91	0.24	1.52	0.14	0.01	0.18
Total	46.20	6.00	33.88	1.38	0.23	12.32

The mass of methane generated was calculated using as follows [3]:

$$M_{CH_4} = \frac{16 \times A_3}{(M_c \times a) + (M_H \times b) + (M_O \times c) + (M_N \times d)} \quad (7)$$

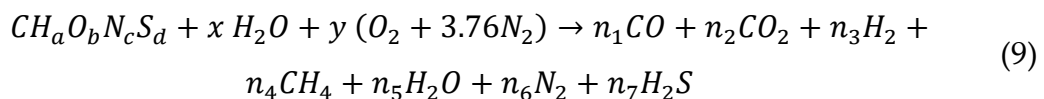
where M_{CH_4} is the mass of methane generated (kg) and M_c , M_H , M_O , as well as M_N are the molar mass (kg/mol) of carbon, hydrogen, oxygen, and nitrogen, respectively. Hence, the amount of energy produced from AD plants was calculated using the following equation [4]:

$$EP = M_{CH_4} \times EC_{CH_4} \times \eta \quad (8)$$

Where EP is the energy production (kWh), M_{CH_4} is the mass of methane generated (kg), EC_{CH_4} is the energy content of methane: 14.31 kWh/kg, and η is the efficiency of energy conversion in the AD process (30%) [1].

1.3 Gasification Plants

The volume of the syngas produced was estimated by the following stoichiometric equilibrium equation [5].



where $n_1, n_2, n_3, n_4, n_5, n_6$, and n_7 represent the number of moles of CO, C₂O, H₂, CH₄, H₂O, N₂, and H₂S, respectively. This equation can be modified to eliminate certain components depending on the desired modeling requirement. For instance, using pure oxygen as a gasifying medium instead of mixed air would change n_6 to $c/2$ and y (O₂ + 3.76N₂) becomes y O₂. Moreover, steam would not be required as a gasifying medium upon processing high moisture feedstock. The atomic balance was performed using the following equations:

$$C: 1 = n_1 + n_2 + n_4 \quad (10)$$

$$H: a + 2x = 2n_3 + 4n_4 + 2n_7 \quad (11)$$

$$O: b + x + 2y = n_1 + 2n_2 + n_5 \quad (12)$$

$$N: c + 7.52y = 2n_6 \quad (13)$$

$$C: d = n_7 \quad (14)$$

where a, b, c , and d represent the chemical composition and were obtained from the results of the ultimate analysis (Table S2). Two additional equations are acquired by analyzing the equilibrium constants (K_{eq}) of the water-gas (Eq. 15) and Boudouard reactions (Eq. 16). At constant pressure, the K_{eq} can be expressed as the ratio of the multiplication of the partial pressure of products to reactants. Therefore, the K_{eq} for the two reactions, related to the Gibbs free energy (ΔG^0), is represented as follows:



At constant pressure, the K_{eq} of a reaction can be expressed by the ratio of the multiplication of the partial pressure of products to reactants, taking into consideration applying Dalton's law of partial pressure, where the ideal gas law is assumed [5]. Therefore, the K_{eq} for the two reactions, being related to the Gibbs free energy (ΔG^0), is represented as follows:

$$\frac{n_1 n_3 P}{n_5 n_7} = \exp\left(-\frac{\Delta G_1^0}{RT}\right) \quad (17)$$

$$\frac{n_1^2 P}{n_2 n_T} = \exp\left(-\frac{\Delta G_2^o}{RT}\right) \quad (18)$$

where P is the total pressure of the system, n_T is the total number of moles (mol), R is the ideal gas constant, T is the temperature of the gasifier (K), ΔG_1^o and ΔG_2^o are the Gibbs free energy (kJ/mol) for the water-gas and Boudouard reactions, respectively. Since H_2 , CO , and CH_4 are the only combustible gases, the higher heating value (HHV) of the syngas was estimated using the following equation:

$$HHV_{syngas} = V_{syngas} \left((HHV_{H_2} \times H_2\%) + (HHV_{CO} \times CO\%) + (HHV_{CH_4} \times CH_4\%) \right) \quad (19)$$

where HHV_{syngas} is the higher heating value of syngas (MJ/m³), V_{syngas} is the total volume of syngas (m³), and HHV is the higher heating value of gas x (MJ/m³). The HHV for H_2 , CO , and CO_2 are reported in literature as 12.76, 12.63, and 39.76 MJ/m³, respectively [6].

1.4 Sanitary Landfill

The energy recovery in sanitary landfills is based on the generation of methane via the decomposition of organic materials, and was calculated as follows:

$$EP = E_{CH_4} \times R \times EC_{CH_4} \times 10^6 \times \eta \quad (20)$$

where EP is the energy production (kWh), E_{CH_4} is the total methane emissions in a year (Gg CH_4 /year), R is the fraction of methane recovered, assumed as 90%, EC_{CH_4} is the energy content of methane (14.31 kWh/kg), and η is the efficiency of energy conversion in landfill gas combustion facilities, assumed as 30% [1].

References

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