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EVALUATION THE ECONOMIC INDICATORS OF WASTE TREATMENT TECHNOLOGIES

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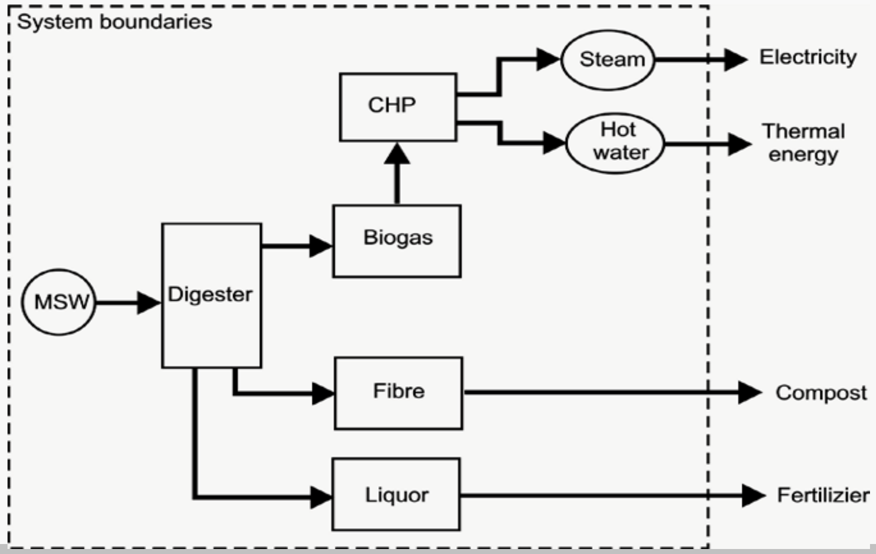
Introduction

- When adopting the economic criteria, for assessing sustainability of waste treatment technique, they are usually associated with certain costs of waste treatment. Unfortunately, cost estimation is relatively crude in solid waste management.
- The most commonly used economic criteria are: investment cost, operation and maintenance cost, revenues, net cost per ton, fuel cost, electricity cost, net present value payback period, service life, etc.
- This paper presented a mathematical model to calculate the economic indicators (investment costs, operating costs and revenues) of biochemical waste treatment technique – anaerobic digestion.
- The model is verified in the case study of the city of Niš.

Anaerobic digestion

- Anaerobic digestion is a biochemical process producing biogas through the biodegradation of organic material in the absence of oxygen with anaerobic microorganisms.
- Biogas released during anaerobic digestion (comprising largely of CH4, 55-60%, and CO2, 30-45%) can be used directly as a fuel for power generation, and has an energy content of 20-25 MJ/m3.
- Typically around 100-350 m3/t of biogas can be produced. Compost can also be obtained as by-product: 1 t of organic waste produces 0.415 t of compost.



Anaerobic digestion

- The capital costs for dry anaerobic composting plant (DRANCO process) capacity of 5,000-100,000 t/y, range from 200-1000 €/t,
- The operating costs range from 40-15 €/t.
- If biogas is utilised in CHP, typically the electricity is produced at 30-35% efficiency and the thermal energy is produced at 40-50% efficiency.
- All products (biogas) and by-products (fibre and liquor) from anaerobic digestion can be used and none of these are landfilled.

Model parameterization and assumptions

- The input variables for the developed model are the amount of waste and waste composition.
- The amount of waste was forecasted over the lifetime of the waste treatment facilities.

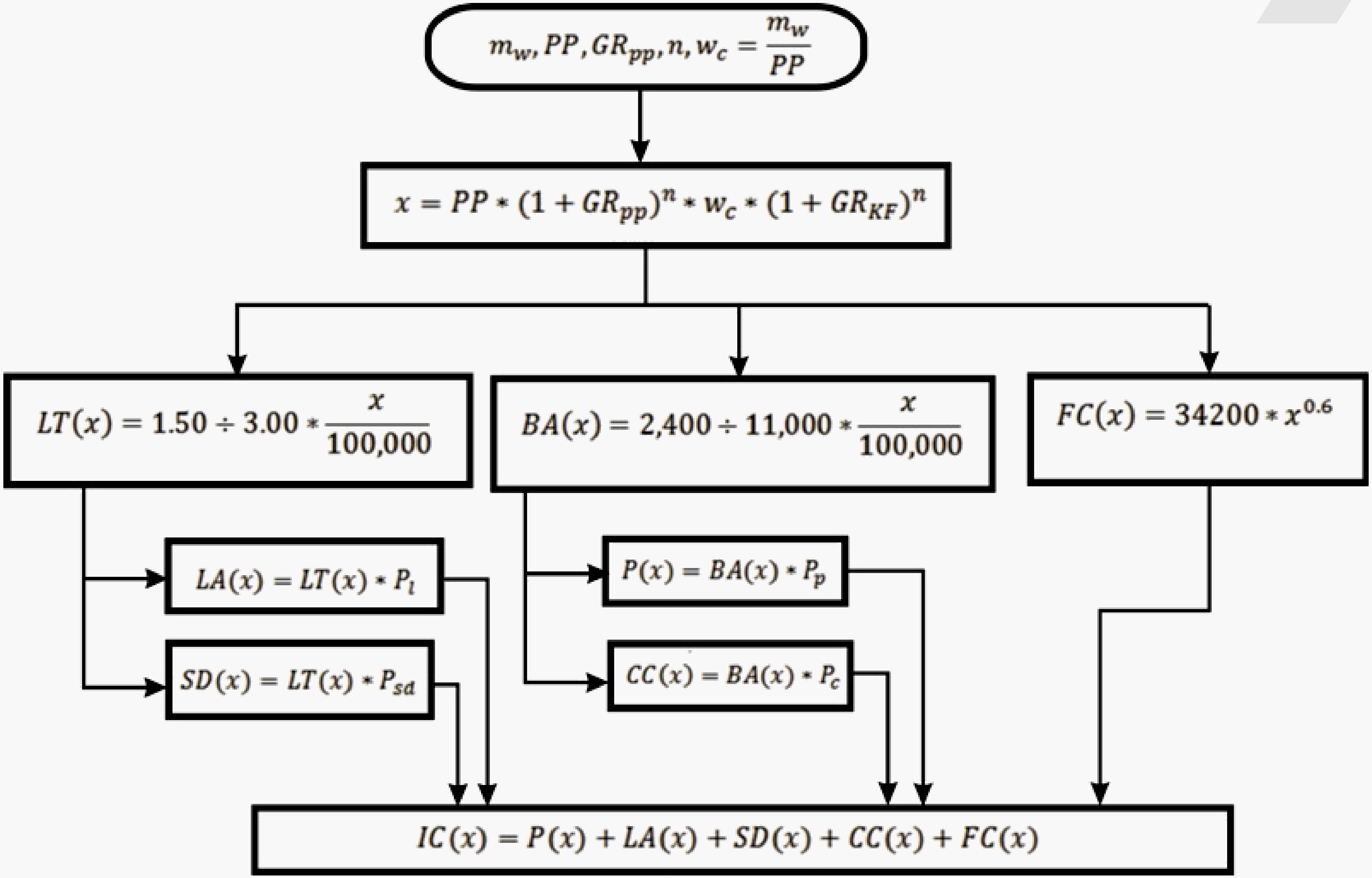
$$x = PP \cdot (1 + GR_{pp})^n \cdot w_c \cdot (1 + GR_{KF})^n$$

- It is assumed that the waste composition does not change during facility lifetime.
- Composition of biogas generated in anaerobic digestion is calculated from the elemental composition (C, H, O, N, S) using a Buswell Equation.

$$C_cH_hO_oN_nS_s + \frac{1}{4}(4c - h - 2o + 3n + 2s)H_2O \rightarrow \frac{1}{8}(4c - h + 2o + 3n + 2s)CO_2 + \frac{1}{8}(4c + h - 2o - 3n - 2s)CH_4 + nNH_3 + sH_2S$$

- Energy yield from biogas is calculated taking into account that the low heating value of methane is 36 MJ/m^3 and assuming that 80% of organic fraction of waste is broken down.

Investment costs

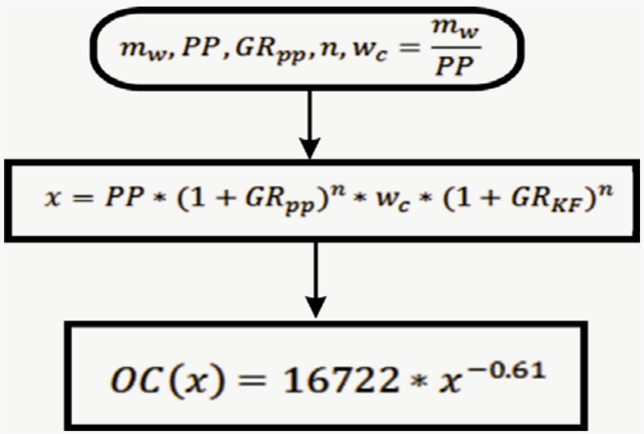


Operating costs

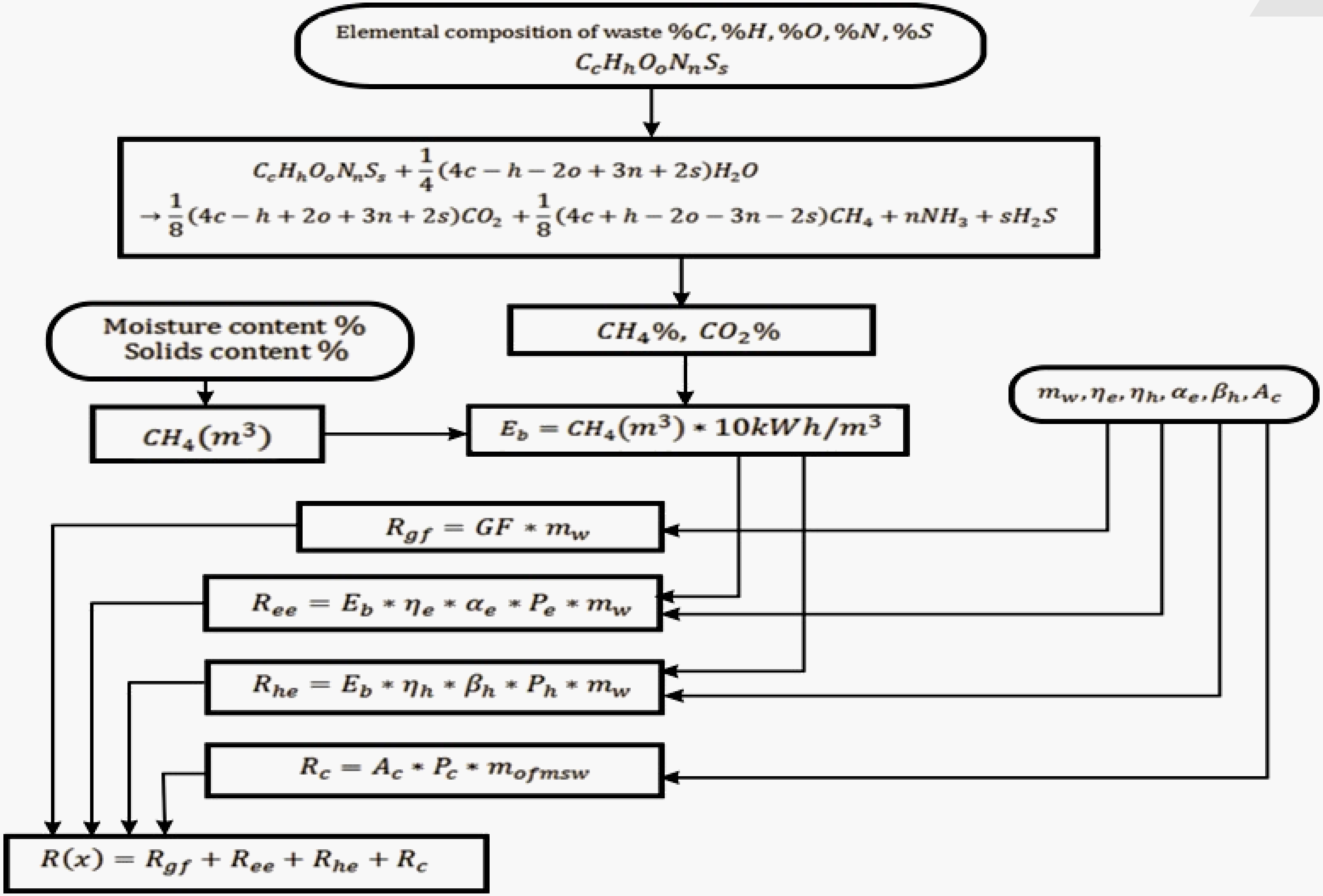
- Operating costs include fixed operating costs and variable operating costs.

$$OC(x) = OC_{fix} + OC_{\mathrm{var}}(x)$$

- The fixed operating costs (OC_{fix}) depend on the number of employees, the percentage of skilled and unskilled workers and engineers, and the local salary level and maintenance costs of buildings and equipment.
- Variable operating costs ($OC_{var}(x)$) consist of costs of chemicals for the flue gas cleaning system, electricity, water and handling of waste water and residue disposal.



Revenues


Elemental composition of waste %C, %H, %O, %N, %S
$C_cH_hO_oN_nS_s$
$C_cH_hO_oN_nS_s + \frac{1}{4}(4c - h - 2o + 3n + 2s)H_2O$
$\rightarrow \frac{1}{8}(4c - h + 2o + 3n + 2s)CO_2 + \frac{1}{8}(4c + h - 2o - 3n - 2s)CH_4 + nNH_3 + sH_2S$
Moisture content %
Solids content %
$CH_4\%,\ CO_2\%$
$CH_4(m^3)$
$E_b = CH_4(m^3) * 10kWh/m^3$
$m_w, \eta_e, \eta_h, \alpha_e, \beta_h, A_c$
$R_{gf} = GF * m_w$
$R_{ee} = E_b * \eta_e * \alpha_e * P_e * m_w$
$R_{he} = E_b * \eta_h * \beta_h * P_h * m_w$
$R_c = A_c * P_c * m_{ofmsw}$
$R(x) = R_{gf} + R_{ee} + R_{he} + R_c$

Results and discussion

Waste quantity and waste composition in the city of Niš

Fraction	Percentage (%)	Production (t/y)	C (% dw)	H (% dw)	O (% dw)	N (% dw)	S (% dw)
Food waste	13.79	9,011.49	48.0	6.4	37.6	2.6	0.4
Paper	7.26	4,744.26	43.5	6.0	44.0	0.3	0.2
Cardboard	4.24	2,770.76	44.0	5.9	44.6	0.3	0.2
Diapers	3.50	2,287.18	35.5	5.67	44.0	<0.1	-
Plastics	21.83	14,265.47	60.0	7.2	22.8	-	-
Textiles	2.63	1,718.65	55.0	6.6	31.2	4.6	0.15
Rubber	5.25	3,430.77	78.0	10.0	-	2.0	-
Leather	0.61	398.62	60.0	8.0	11.6	10.0	0.4
Yard waste	13.55	8,854.65	47.8	6.0	38.0	3.4	0.3
Glass	5.39	3,522.26	0.5	0.1	0.4	<0.1	-
Metals	1.62	1,058.64	4.5	0.6	4.3	<0.1	-
Dirt, ash, etc.	20.33	13,285.25	26.3	3.0	2.0	0.5	0.2

Results and discussion

Input data in calculation

Amount of waste (t)	65,348	Land price (€/m^2)	1,000-3,000
Forecasted plant capacity (t)	171,320	Site development costs (€/m^2)	20
Facility lifetime (y)	20	Project and permits costs (€/m^2)	40
Biogas composition	57.42% CH_4 42.58% CO_2 3.13% NH_3	Construction costs (€/m^2)	450
Amount of methane per ton of waste (m^3)	290	Gate fee (€/t)	20
Energy yield from biogas (kWh/t)	2,905.35	Preferential prices for energy from waste (c€/kWh)	12
Amount of compost per ton of waste (t)	0.415	Selling rate of produced energy	1
Energy efficiency (%)	30	Selling rate of produced heat	0.55
Thermal efficiency (%)	45		

Results and discussion

Investment costs (€)		Operating costs (€)	
LT (ha)	4.70	**OP (€ / t)**	**10.73**
LA (€)	14,133.94	**Revenues (€)**	
SD (€)	9,422.63	Rgf (€)	815,673.60
BA (m^2)	11,478.48	Ree (€)	4,265,663.97
P (€)	459,139.04	Rhe (€)	2,349,498.85
CC (€)	5,165,314.20	Rc (€)	507,756.82
FC (€)	47,240,203.83	R (€)	7,938,593.23
I (€)	52,888,213.65	**r (€ / t)**	**121.48**
i (€ / t)	**308.71**		

Results and discussion

- The investment costs of 308.71 €/t are at the lower limit of the costs in the EU, due to the lower price of land, constructing costs, salary levels, etc.
- The operating costs are lower than EU average: they amounted to 10.73 €/t.
- The calculated total revenues are 121.48 €/t and they are at the upper limit of EU average, due to the higher state subsidies, i.e. higher prices of electricity produced by waste treatment. In Serbia the electricity price obtained from anaerobic digestion is 12 c€/kWh for, while the EU electricity prices range from 2.0–4.0 c€/kWh.

	Serbia	**EU average**
Investment costs (€/t)	308.71	300.00 – 1000.00
Operating costs (€/t)	10.73	15.00 – 40.00
Revenues (€/t)	121.48	56.00 – 126.00

Conclusion

- The presented model is based on the analysis of the structure of investment and operating costs, and revenues, as well as local economic conditions.
- All of the above indicators are calculated depending on the composition and quantity of waste.
- For each indicator an algorithm that predicts several steps for its calculation is presented.
- The developed model is sufficiently general to be applicable to any case study, because it contains local elements (price of land, construction cost, design and permit prices, price of the produced electricity and heat, gate fee, the price of compost).

THANK YOU!