The first municipal solid waste incinerator project in Southeast Europe

Ana Nikolic, Miljan Mikic
& Zorana Naunovic

University of Belgrade
Faculty of Civil Engineering
Belgrade, Serbia

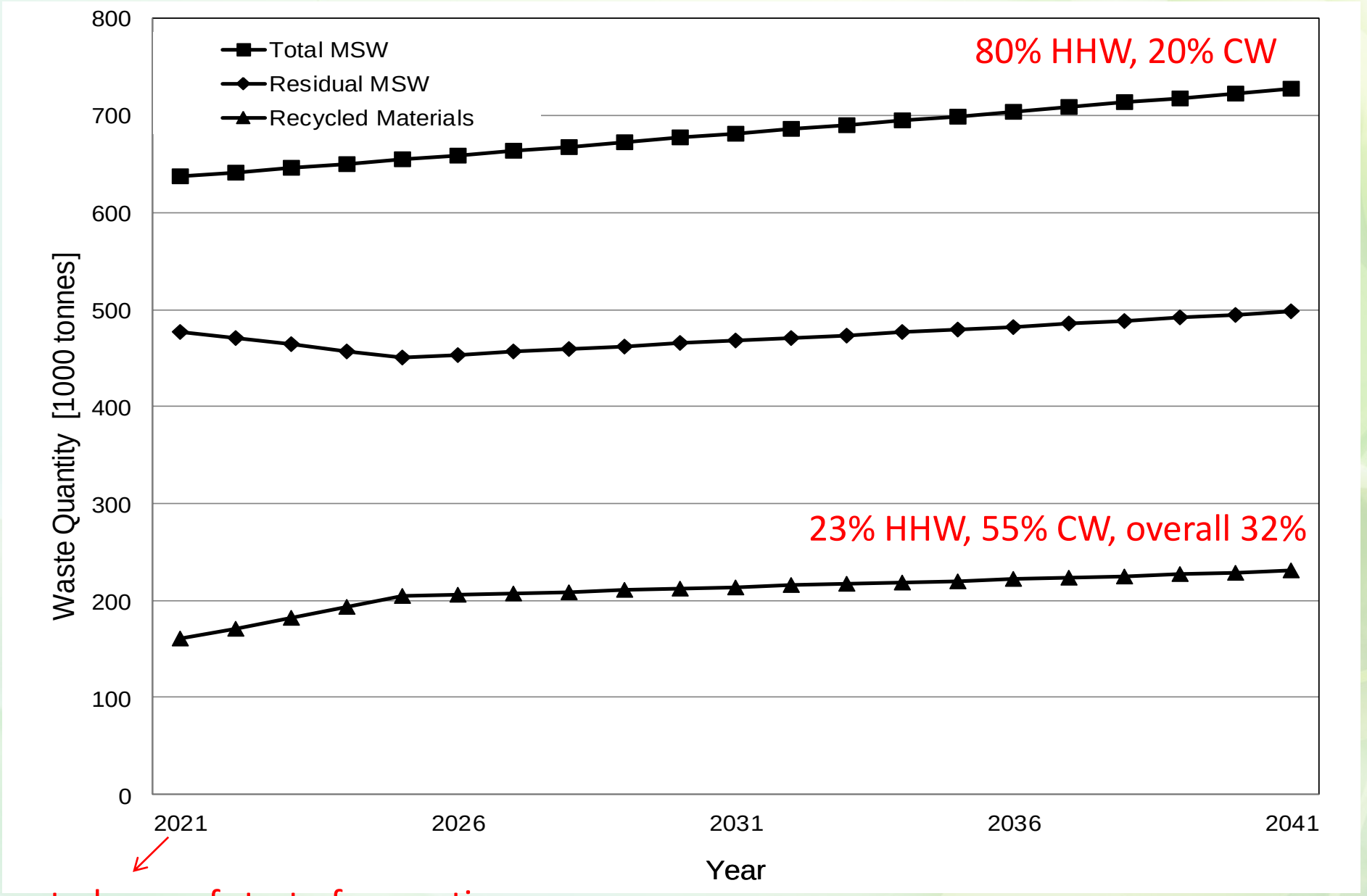
Introduction

- The City of Belgrade, the capital of Serbia, is in the project preparation phase for a public-private partnership (PPP) project for the provision of services of treatment and disposal of residual municipal solid waste (MSW), including the construction and operation of a waste to energy (WtE) facility.
- The objective of this work was to perform a sustainability analysis, done in the form of a social cost-benefit analysis (CBA), to assess the financial, environmental and social effects of a WtE project in Belgrade.
- The contributions of energy derived from waste incineration to the total energy consumption in Belgrade were also evaluated.

Current MSW management practices in Belgrade

- Recycling of packaging waste, primarily from commercial sector (30%)
- Waste disposal at the Vinca unsanitary landfill located 15 km from Belgrade, on the right bank of the River Danube.
- The landfill site has been in operation since 1977, the landfill body has an area of 45 ha and a height of 5 to 50 meters.
- There is no collection of landfill gas and leachate drains though a canal into a natural swamp within the Danube riverbed.

Projected municipal waste quantities



expected year of start of operations

MSW characterisation

Waste Fraction [%]	MSW	Residual MSW	LHV (wet basis) [MJ kg^{-1}]
Food waste	26.3	38.8	3.8
Paper/ Cardboard	22.2	8.2	12.2
Plastics	13.9	9.2	35.3
Textile	3.9	5.8	18.5
Diapers	4.0	5.9	11.1
Leather	1.1	1.6	22.9
Yard waste	6.7	9.9	5.9
Wood	1.1	0.6	15.6
Glass	5.5	2.0	0
Metals	3.6	1.3	0
Inert	11.2	16.5	0
Hazardous waste	0.5	0	
Total	100	100	

- EU Circular Economy package - targets for the reduction of waste components by 2025: 75% for paper and cardboard; 55% for plastics; 75% for glass; 75% for metals; and 60% for wood.
- It was assumed that the stated recycling goals would be fulfilled and that hazardous waste would be source-separated and not incinerated.
- The LHV of MSW prior to recycling and residual MSW were calculated to be 10.6 MJ kg^{-1} and 8.5 MJ kg^{-1}, respectively.

Combined heat and power (CHP) system

- The chosen WtE combustion technology was mass burn grate incineration with energy recovered in the form of electricity and heat.
- Belgrade has a developed district heating system with an overall length of the heating route of 1420 km that services about half of the population in Belgrade.
- Locating the WtE facility next to an existing thermal power plant would enable the utilization of the heat energy produced by incineration.

Energy generation

- The energy yield from a CHP incinerator facility was calculated based on World Bank recommendations where one tonne of residual MSW with a LVH of 8.5 MJ kg^{-1} yields:
  - 0.47 MWh of electrical energy
  - 1.53 MWh of heat
- In its first year of operation, the incinerator produces:
  - 224 GWh of electrical energy (6% of the electrical household demand in 2014)
  - 729 GWh of heat (26% of the thermal energy delivered during the 2014/2015 heating season in Belgrade)

Financial analysis

- Initial capital investment (I) and annual operation cost (OC) cost function:

$$I = 5000 \cdot NC^{0.8}\ [€]$$
$$OC = 700 \cdot NC^{-0.3}\ [€t^{-1}]$$

Tsilemou K, Panagiotakopoulos D.: Approximate cost functions for solid waste treatment facilities. Waste Manage Res 24(4):310-322 (2006)

- NC = 550,000 tonnes residual MSW per year
- I = €239 million
- OC = €16.5 per tonne of residual MSW
  (€7.9 million and €8.2 million in the first and last year of operation, respectively)

Financial analysis (millions €)

FDR	4.5%													
Year	1	2	3	4	5	6	7	8	9	10	15	19	20	25
I	8.9	10.6	105.9	113.2										
OC					7.9	7.8	7.7	7.6	7.4	7.5	7.7	7.9	8.0	8.2
RC												164.3		
CDC														9.5
Total Outflow (TO)	8.9	10.6	105.9	113.2	7.9	7.8	7.7	7.6	7.4	7.5	7.7	172.3	8.0	17.8
Treatment revenue					19.4	19.5	19.6	19.6	19.7	19.8	20.1	20.3	20.3	20.7
Electricity revenue					18.8	18.8	18.5	18.3	18.0	17.8	18.3	18.8	18.9	19.5
Heat revenue					26.6	26.6	26.3	25.9	25.6	25.2	26.0	26.6	26.8	27.6
Total Inflow (TI)					64.9	64.9	64.4	63.9	63.3	62.7	64.4	65.7	66.0	67.8
TI – TO	-8.9	-10.6	-105.9	-113.2	57.0	57.2	56.7	56.3	55.9	55.2	56.7	-106.6	58.0	50.1
FNPV(C)	360													
FRR(C)	19.6%													

- RC – replacement costs; CDC - clearance and decontamination cost

- Treatment revenue: monthly incineration gate fee €1 per resident
- Electricity revenue: Electricity feed-in tariff €87.4 per MWh
- Heat revenue: Natural gas based heat production price €42 per MWh
- Financial Net Present Value (FNPV) of the project positive (€360 million)
- The generated revenues are higher than the investment costs and that the project does not require any external financial support.

Economic analysis

- Project social and environmental acceptability – benefits and costs to society
- Non-market impacts: reduction of greenhouse gas (GHG) emissions due to:
  - the diversion of biodegradable waste from landfill
  - partial replacement of fossil fuels used for the generation of heat and electricity
- The economic value of the reduction of GHG emissions emitted to the atmosphere was conducted by multiplying the amount of emissions avoided (CO_2-equivalents per year) by their unit cost expressed in Euro per tonne.

Economic analysis - Monetisation of non-market impacts or externalities

- The externality that most importantly contributes to climate change mitigation and is the most significant in monetary terms is the reduction of greenhouse gas (GHG) emissions due to:
  - the diversion of biodegradable waste from the landfill where it decomposes under anaerobic conditions and creates methane
  - partial replacement of fossil fuels used for the generation of heat and electricity
- The economic value of the reduction of GHG emissions emitted to the atmosphere was conducted by multiplying the amount of emissions avoided (CO_2-equivalents per year) by their unit cost expressed in Euro per tonne.

Economic analysis (millions €)

SDR	5.5%													
Year	1	2	3	4	5	6	7	8	9	10	15	19	20	25
I	7.8	9.3	93.1	99.5										
OC					6.7	6.6	6.6	6.5	6.4	6.4	6.6	6.8	6.8	7.0
RC												144.4		
CDC														5.7
Total economic cost (TEC)	7.8	9.3	93.1	99.5	6.7	6.6	6.6	6.5	6.4	6.4	6.6	151.2	6.8	12.7
Treatment revenue					19.1	19.1	19.2	19.2	19.3	19.4	19.7	19.9	19.9	20.3
Electricity revenue					18.8	18.8	18.5	18.3	18.0	17.8	18.3	18.8	18.9	19.5
Heat revenue					26.6	26.6	26.3	25.9	25.6	25.2	26.0	26.6	26.8	27.6
Avoided GHG emissions due to diversion of biodegradable waste from landfill					3.4	3.4	3.3	3.2	3.2	3.2	3.0	2.7	2.6	1.8
Avoided GHG emissions from partial replacement of fossil fuels used for generation of heat					6.8	6.9	7.0	7.1	7.2	7.4	8.5	9.1	9.2	10.0
Avoided GHG emissions from partial replacement of fossil fuels used for generation of electricity					13.7	13.9	14.1	14.3	14.4	14.9	17.0	18.2	18.5	20.1
Total economic benefit (TEB)					88.5	88.8	88.4	88.1	87.7	87.8	92.4	95.2	95.9	99.3
TEB-TEC	-7.8	-9.3	-93.1	-99.5	81.7	82.1	81.9	81.6	81.3	81.4	85.8	-56.0	89.0	86.5
ENPV	611.4													
ERR	31.8%													

- Positive economic net present value (ENPV) (€611.4 million) indicates that the project is desirable from a socio-economic perspective.

Results

- Electrical energy produced by incineration will reduce the amount of coal burned in power plants that currently supply Belgrade with electricity.
- The financial and economic analyses, done in the form of a CBA, showed that the project was financially and economically positive.
- The Belgrade WtE facility project is a first-of-its-kind in the region. The presented work could serve as a primer on conducting a WtE project sustainability analysis for other cities and urban areas in the region that do not have developed WtE systems.

Thank you for your attention

Zorana Naunovic

znaunovic@hikom.grf.bg.ac.rs

Current status

- Pre-qualified bidders who have entered the dialogue phase with the City of Belgrade
  1. Joint application: Wte Wassertechnik, GMBH, Ruhrallee 185 45136 ESSEN, Germany, Kommunal-und Industrieentsorgung Jessen GMBH, Grosskorggaer Landstr. 4 06917 Stadt Jessen/Schweinitz Germany;
  2. Suez environnement, Tour CB 21-16 Plazede l`iris 92040, Paris la defense;
  3. Urbaser, S.A. N.I.F.: A-79524054, Caminode Hormiguesras 28031, Madrid;
  4. Joint application: Veolia Central and Eastern Europe Eneris Surowce S.A., 36 Avenue, Kleder 75016, Paris, France;
  5. Beootpad doo Beograd, Str. Mokroluska Nova 5, 11050, Beograd 22, Serbia.

Financial analysis

- Additional financial outflow:
  - the replacement costs (RC) of short life facility components in the 19th year of project life cycle (adopted as a 75% of the facility and equipment costs); and
  - the clearance and decontamination cost (CDC) of the project site at the end of the operational period (assumed to be 4% of the initial capital investment or €9.5 million).

Economic Analysis - Monetisation of non-market impacts or externalities

- The unit cost of GHG emissions was €32 and €50.5 per tonne of CO_2-eq at the start and end of the project cycle, respectively, as recommended by European Investment Bank.
- The avoided GHG emissions due to diversion of biodegradable waste from landfills were quantified by calculating the difference between the GHG emissions that emanate from landfills and the WtE facility based on data from the Guide to CBA of investment projects.
- The GHG landfill emissions were 0.67 tonnes CO_2-eq per tonne of landfilled waste at the start of the project cycle and decreased to 0.62 t CO_2-eq per tonne of waste at the end of the project cycle, due the assumed changes in the composition of residual MSW where the organic and plastic waste contents will decrease and increase, respectively.

Economic Analysis - Monetisation of non-market impacts or externalities

- The GHG emission from the WtE facility ranged from 0.47 to 0.55 t CO_2-eq per tonne of incinerated waste.
- The calculated difference between the GHG emissions that emanate from landfills and the WtE facility ranged from 0.2 to 0.07 t CO_2-eq per tonne of waste during the project life cycle.
- The avoided GHG emissions for energy recovered in the form of heat were based on the GHG emission factor for natural gas based district heating systems of 0.26 kg CO_2-eq per kWh.
- The GHG emission factor of 1.7 kg CO_2-eq per kWh for lignite was taken from the same source for calculation of avoided GHG emissions through energy recovery in the form of electricity.

Economic Analysis - Monetisation of non-market impacts or externalities

- Other positive externalities of the improved waste management achieved through the project are not computed in this case because they were found to be insignificant in monetary terms as compared to those from avoided GHG emissions, e.g. the avoided emissions of pollutants to air, such as NOx, SO_2 and fine particulate matter through the displacement of coal as fuel in energy generation, or the avoided soil and groundwater contamination through municipal waste landfills.
- Negative externalities:
  - other emissions from the WtE plant to air, water and soil: minimised through the inclusion of BAT for the treatment of flue gases, incineration ashes and wastewater produced in the plant as well as the safe disposal of ashes (all of which are internalised in the cost of the project)