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Original Research

Waste-to-Energy in Transition Countries: Case Study of Belgrade (Serbia)

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Abstract

This paper gives an overview of the current situation in the field of energy and municipal solid waste management (MSWM) in Serbia with the emphasis on identification of opportunities and challenges related to obtaining energy from municipal solid waste (MSW) on a specific example of the future waste management center in Belgrade (Serbia). This waste management center will be equipped with two plants for energy production, from waste and from landfill gas. These plants will annually produce about 216 GWh of electricity and about 174 GWh of heat. The importance of such a project is manifold because it solves the long-standing problem of waste management in Belgrade based on landfilling at the non-sanitary landfill Vinca, which is a great burden on the environment with potential risk to human health, while introducing a new dimension in energy production in Serbia.

Keywords: waste-to-energy, municipal solid waste, waste management, policies

Introduction

The World Bank Group has assessed that the global average generation rate of municipal solid waste (MSW) in 2016 was approximately 0.74 kilograms per capita per day, with 2.01 billion tons generated overall. The increase of MSW global production is expected, with the annual growth of 1.5% that will lead to the production of 3.0 billion tons of MSW in 2030. An average amount of waste generated in developing countries amounts to about 0.54 kg of waste per capita per day, and it has been projected that the waste production in 2030 will reach 0.63 kg of waste per capita per day, with the annual growth of 1.1% [1]. Countries with higher Gross Domestic Product (GDP) commonly produce larger quantities of waste, therefore the continual rise in MSW production is, among other factors, determined by population growth, improvement of the GDP and urbanization [2].

In developing or transition countries, including the Republic of Serbia, a major problem is the low development of the MSW management system, together with the wrong approach that is largely based on the disposal of waste at illegal and non-sanitary landfills [3]. Over two -thirds of MSW are placed in open dumpsites in developing countries. This kind of waste -depositing practices could lead to an exceedingly adverse influence on public health and the environment. One of the possible solutions to overcome this problem would be to reduce the amount of waste that requires

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discarding on land by applying measures to reduce waste production at the source. Additionally, adequate categorization and separation of different types of wastes would help enhance recycling, while converting waste to clean energy (WtE) could also be one of the promising and achievable solutions [4, 5].

The progress in the field of WtE can prolong the lifespan of landfills and considerably lessen the need of land for disposal. It has been indicated that developed economies manage to generate around 500 to 600 kWh of net electric energy per ton of waste used as a fuel, while in developing or transition countries this numbers can go up to 300 to 400 kWh per ton. Of course, the quality and calorific value of MSW are very variable due to differences in waste content. The waste in developing or transition countries is known to have high content of food waste, high moisture content and almost no waste sorting. Thus, the calorific value of such MSW is consequently lower [4].

According to the environmental strategies and action plans of the European Union and the waste management hierarchy as it's integral part, the order of priorities in waste management has been determined in order to minimize its disposal [6]. This concept has also been implemented in the legal acts of the Republic of Serbia related to waste management, but unfortunately in practice it is still not sufficiently applied, which is one of the main reasons for the existence of non-sanitary and illegal landfills.

In Serbia, 3,582 landfills have been identified, majority of which have a relatively small volume of waste (less than 10,000 m³) [7]. However, there are 50 identified landfills with a waste volume of more than 100,000 m³ that are responsible for the emission of approximately 60,000 tons of CH_4, which is more than 95% of the total CH_4 emissions from the waste disposal. In addition to emitting harmful gases into the atmosphere, these landfills are often greatly responsible for the soil and water pollution since about 20% of landfills are at a distance of less than 1 km from water sources. Also, due to the poor condition of the landfills, the occurrence of the fires and explosions is possible, as was the case with the Vinca landfill, when in 2017 dozens of fires were registered in the body of the landfill. From the total number of landfills, 164 belong to the group of controlled municipal landfills, while 3,418 are illegal/uncontrolled type of landfills. Controlled municipal landfills in Serbia are considered to be the official disposal sites, i.e. locations were only official PUCs/Operators dispose of collected municipal waste, but in most cases these landfills still do not meet the minimum standards. All other locations are defined as uncontrolled landfills or "dumpsites". About 20% of generated waste in Serbia that is not covered by the organized waste collection is disposed at uncontrolled landfills [8]. There are also 10 sanitary landfills, which serve about 20% of the population.

Due to the inadequate system of MSWM in the Republic of Serbia, a large amount of waste ends up at non-sanitary landfills, without any prior treatment, thus creating a negative impact on all environmental media and potentially human health. Inadequate waste management system also poses a serious problem the Serbian capital Belgrade, where the Vinca landfill has created major problems related to environmental pollution. One of the main consequences of this problem is air pollution due to uncontrolled emission of landfill gas from the landfill body, as well as frequent fires that occur due to self-heating of the organic part of the waste. Organic waste decomposes aerobically in the presence of oxygen, whereas in the absence of oxygen it decomposes anaerobically while releasing heat, which can easily lead to fire [9-11]. With high outdoor temperatures, fires are almost always present at the Vinca landfill in the summer months. Furthermore, because of the temperature increase in the landfill body and increased landfill gas emissions, explosions are frequent and pose an immediate threat to landfill employees [12]. Another major problem of the Vinca landfill is the production of leachate that has not been subjected to appropriate treatment, and represents the main source of soil and groundwater pollution. Landfill Vinca is a threat to neighboring communities, biodiversity and ultimately to ground waters and to the Danube. Consequently, it is evident that the current waste management system in Belgrade must be transformed into a sustainable system from the aspect of environmental protection, primarily through activities of remediation of the existing landfill body, but also through future additional use of resources and energy from waste.

The energy security of the Republic of Serbia mostly depends on fossil fuels (oil and natural gas), which are imported, and which are often sensitive to supply disruptions, as well as to the fluctuation of energy prices on the world market. That is one of the main reasons why it is of great importance to use the energy potential of the waste, which could be converted into electrical and thermal energy using appropriate technologies.

There are numerous technological possibilities for the conversion of MSW into the energy (Waste-to-energy), such as: incineration, refuse derived fuel (RDF), biogas production by anaerobic digestion, pyrolysis [13], gasification and landfill gas recovery [14]. In addition, landfill gas generated by anaerobic decomposition of organic waste within the landfill can be used in several ways, from its combustion in CHP plants to obtain electrical and thermal energy, to its purification and distribution to end users [15].

The aim of this paper was to analyze the future waste management plan in Belgrade based on the construction of a waste incineration plant and the use of its energy potential. As MSW is considered to be a renewable energy source (RES) [16, 17] and represents an important resource in the energy system of the Republic of Serbia, this paper also presents the legal framework for the use of RES.

Materials and Methods

Energy Sector Legislation

With the package of measures "Climate and Energy Package EU 2020" adopted in 2009, the European Union defined a set of goals in the energy sector and climate change that had to be realized by 2020. The package defines three key targets: reducing greenhouse gas emissions by 20% (compared to 1990 levels), 20% of energy has to be from the renewable sources, and an increase in energy efficiency by 20% [18].

These goals have been adopted to make the EU a highly energy-efficient, low-carbon society. Moreover, in 2014, the "Climate and Energy Framework 2030" was adopted, which sets three even more ambitious goals for the year 2030. The first goal is to reduce greenhouse gas emissions by at least 40% (compared to 1990 levels). The second goal is to increase the share of RES to at least 27%, which also contributes to the establishment of a safer, more competitive and sustainable energy system. The third and final goal is to increase energy efficiency by at least 27% [19].

By including Serbia in the EU accession negotiations, harmonizing and transposing the relevant directives and laws, Serbia has made significant progress in the field of energy, environmental protection and climate change. In accordance with the contract on the establishment of the Energy Community between the European Community and 9 signatory countries, the Republic of Serbia accepted the obligation to implement two European Directives in the field of RES [20, 21], which were later replaced by Directive 2009/28/EC [22]. Within the framework of Directive 2009/28/EC, one of the goals set for the members of the European Union is for RES to participate with a 20% share in gross final energy consumption by 2020. In accordance with the mentioned Directive and the Decision of the Ministerial Council of the Energy Community from October 2012, a very ambitious and binding target was set for Serbia to participate with 27% of RES in its gross final energy consumption by year 2020 [23]. The National Action Plan for the Use of Renewable Energy Sources (NAPRES) is a document that sets goals for the use of RES by year 2020, as well as the way to achieve them. In addition, it aims to encourage investment in the renewable energy sector. The NAPRES presents clear goals and criteria for the participation of energy from RES in the electrical energy sector, in the heating and cooling energy sector and in the transport sector. In the electrical energy sector, the share of RES will be 36.6% (instead of the previous 28.7%), in the heating and cooling sector the share of RES will be 30% (instead of the previous 25.6%) and in the transport sector 10% (instead of the previous 0%) [23].

The new Law on Energy of the Republic of Serbia [24] regulates the goals of energy policy and the manner of its realization, conditions for reliable, safe and quality delivery of energy and energy products and conditions for secure supply to customers. In addition, the law standardizes regulations related to the protection of energy customers and energy sources, conditions and methods of performing energy related activities, conditions for construction of new energy facilities, the use of RES, incentive measures, ways of proper organization and functioning of the market for electricity, natural gas, oil and oil derivatives, as well as supervision over the implementation of this law.

Based on the adopted Strategy for the Development of the Energy Sector of the Republic of Serbia for the period until year 2025 with projections until year 2030, the strategic development of energy sector is based on establishing a balance between energy production from available sources, energy consumption with a marketing and socially sustainable character and more efficient production and use of the cleanest energy from RES [25].

Waste Management Legislation

MSWM should respect waste hierarchy, i.e., to reduce the environmental impact in accordance with the instruction for waste minimization, reuse, recycling, energy recovery, and landfilling [26]. The legislation associated with waste management requires the exploration for economic and environmental mechanisms that can provide the solution of the waste disposal problem. Serbia has made significant progress in harmonizing existing laws with current EU legislation. Crucial documents which regulate waste management systems in Serbia are: The National Waste Management Strategy [27], Law on Waste Management [28], Decree on Waste Landfilling [29] and the Law on Packaging and Packaging Waste [30].

Adopted in 2002, National Waste Management Strategy (NWMS) represented first document with aim to strategically organize waste management system on national level, by forming 27 different waste management regions in country. Currently, a Draft National Waste Management Strategy with a National Plan for the period 2020-2025 has been prepared, which further develops the regional approach to MSWM and sets goals in line with the EU acquis. The main focus is on the selection of waste at the source, enhancement of the level of waste recycling and building the missing infrastructure in order to create the basis for meeting the goals set out in the key EU Directives in the waste sector. NWMS [27] define short and long - term objectives, which in context of future MSWM, amongst others include:

- By the end of 2030, it is necessary to increase the rate of recycling of MSW from households to 35 wt%; to 45 wt% by the end of 2035 and finally 65 wt% by the end of 2054.
- By the end of 2029, it is required that the increase of the diversion of paper and cardboard from

the landfills, in relation to their total generated mass, reach 35%, and 50% by the end of 2034.
- By the end of 2029, the increase of the diversion of bio-waste from the landfills should reach 40% of its total generated mass, and 60% by the end of 2034.
- By the end of 2028, the amount of biodegradable waste disposed on the landfills should be reduced to a maximum of 75% of the mass of biodegradable waste generated and landfilled in 2008; to a maximum of 50% by the end of 2032 and to a maximum of 35% by the end of 2039.
- By the end of 2028, comply and reach objectives for the waste collection and recycling as defined in Directive 94/62/EC (Packaging and Packaging Waste Directive)
- By the end of 2035, it is necessary to comply and achieve the targets for the waste collection and recycling as defined in the framework of Directive (EU) 2018/852 (amended PPW Directive)
- By 2035 comply with the collection and recycling targets of Directive 2006/66/EC.
- Specific directions and obligations that stipulate the construction of waste-to-energy plants indicate building of incinerator for MSW in Belgrade, until 2024.

Assuming that that majority of generated MSW (i.e. 510,000 t/year) will be incinerated or disposed at a sanitary landfill, Belgrade WM region may not be able to completely achieve mentioned recycling targets. Given that recycling rates are considered on overall national level and the fact that National Waste Management Strategy already recognized incineration as a main treatment option for Belgrade, focus should be on the rest of the waste flow, i.e., on maximum utilization of the recyclable materials which will not be delivered to Vinca WM center. At a later stage, there is possibility that certain quantities of commercial, non-hazardous industrial waste, as well as RDF (as an output fraction from waste separation lines from other WM regions) will provide the required quantities for incineration, while the "surplus" of recyclable waste stream in Belgrade can be recycling-oriented and thus help the achievement of national goals.

Electricity Production in Serbia

Constant growth of industrialization and continual technological progress has resulted in increased electrical energy consumption, and consequently the need to increase its production. At the same time, one of the largest sources of air pollution in Serbia is the electricity generation sector, which is based on eight thermal power plants in which domestic lignite of very poor quality is used as fuel [31, 32]. All thermal power plants are few decades old and are not equipped with modern flue gas purification systems that would make their production process less harmful to the environment [33].

Table 1 provides an overview of the gross electricity production in the Republic of Serbia for year 2020. As can be seen, about 70% of the total produced electrical energy is obtained from the mentioned thermal power plants, while about 30% is obtained from the RES. Owing to such a high percentage of RES, Serbia has gained a respectable position in the EU Energy Community, because it has achieved the projected percentage of the RES [34]. However, the fact is that large hydropower plants have a dominant share in this percentage, while the share of all other RES is around 3%.

Serbia generates 2.46 million tons of MSW annually [35], which represents a significant energy potential,

Table 1. Gross electricity production in the Republic of Serbia [34].

Gross electricity production	Realized 2018.		Estimated 2019.		Planned 2020.	
	[GWh]	[%]	[GWh]	[%]	[GWh]	[%]
Thermal power plants (lignite)	24,975	66.73	26,295	68.73	27,865	70.71
Thermal power plants (natural gas and fuel oil)	280	0.75	346	0.90	123	0.31
Hydropower plants	10,999	29.39	9,885	25.84	9,322	23.66
Small hydropower plants	394	1.05	287	0.75	347	0.88
Solar power plants	13	0.03	14	0.04	19	0.05
Wind farms	150	0.40	848	2.22	1079	2.74
Biogas power plants	102	0.27	116	0.30	161	0.41
Biomass power plants	0	0.00	0	0.00	20	0.05
Landfill gas power plants	0	0.00	0	0.00	0	0.00
Small high efficiency CHP (natural gas)	97	0.26	108	0.28	99	0.25
Industrial power plants (natural gas and fuel oil)	415	1.11	363	0.95	371	0.94
Total	37,426	100	38,261	100	39,405	100

but as shown in Table 1, there is still no electrical energy generation in Serbia from MSW and landfill gas.

Since Serbia is in the process of joining the European Union, it is of great importance that the development of the MSWM system is accompanied by the adoption of new technologies, such as the use of MSW for the purpose of electrical energy production. The process of converting MSW into energy is environmentally, economically and socially sustainable.

Results and Discussion

Sources and the Amount of MSW in Belgrade

As mentioned earlier, there are more than 3,500 legal and illegal landfills in Serbia where MSW is disposed and not properly treated. In addition to MSW, the landfill often contains hazardous industrial and medical waste, construction waste, motor oils, emulsions and other types of hazardous waste.

An example of one such landfill, which is also the largest in Serbia in terms of size, is the landfill in Vinca. The Vinca landfill is located in the settlement of the same name, on the right bank of the Danube, in the eastern part of the city of Belgrade and is only 10.5 km away from the Belgrade city center (Fig. 1). It was formed in 1977, when the composition and impermeability of the soil met the legal requirements for the construction and operation of the landfill, which is not the case today. It is the only landfill for the city of Belgrade where 13 out of 17 city municipalities dispose their waste. Waste has been disposed of at the site for more than 40 years, and on average about 550,000 tons of waste is delivered to the landfill annually, which represents between 20-25% of the total generated MSW in Serbia. The landfill covers an area of 76 ha, the height of the disposed waste is 30 to 40 m, and the volume of waste at the landfill is about 12.7 million m^3 [36].

With time, Vinca became typical non-sanitary landfill, which resulted in the pollution of the local watercourses (Danube River), together with contamination of the surrounding agricultural land due to leachate that is not collected and treated despite the fact that it contains a high percentage of organic matter and heavy metals. Furthermore, there is no controlled release of landfill gas generated by anaerobic decomposition of biodegradable waste in the landfill. This often leads to fires or explosions, which, in addition to air pollution, endanger the safety of workers at the landfill.

Table 2 shows the basic data on the source and the amount of MSW that is disposed of at the Vinca landfill. The four measuring campaigns conducted during the year showed that the average amount of the collected waste is 532,860 tons per year. The number of inhabitants covered by the organized collection of MSW is 1,339,705 or 81% of the total population of the city of Belgrade. The main reasons for that are the existence of local utility companies in the remaining 4 municipalities (out of 17) that collect waste, as well as the existence of the illegal landfills, on the territory of the city, where the rest of the waste is illegally disposed. One resident of the capital generates an average of 398 kg of waste during the year, or 1.09 kg on a daily basis. The mentioned data is influenced by several parameters: the purchasing power of the population, the structure of the household and the way of life. Parameters that also impact mentioned data are the geographical position

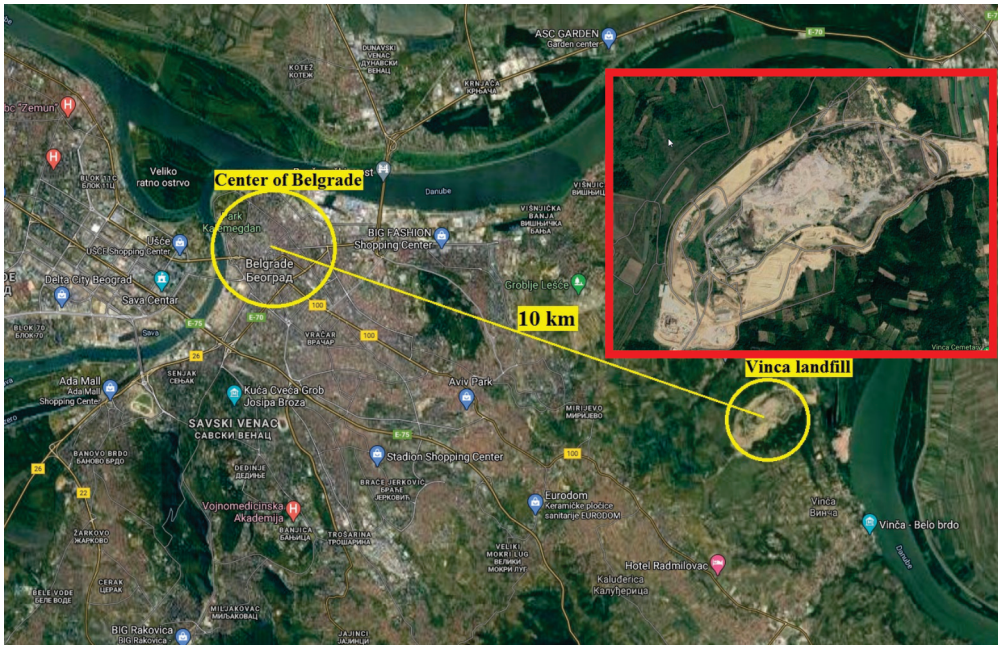

Fig. 1. Position of the Vinca landfill in relation to the center of Belgrade.

Table 2. Projection of obtained results, for four different seasons and the average value [35]

City of Belgrade					
Number of residents	1,659,440				
Population covered by organized waste collection (In 11 out of 17 city municipalities the waste collection is performed by PUC „Gradska čistoća" - Belgrade and the waste is delivered to Vinca WM center)	1,339,705				
Share of population under organized waste collection	81%				
Waste amount	Summer	Autumn	Winter	Spring	Average
Total collected waste amount delivered to Vinca WM center [t/year]	548,855.71	524,035.71	547,865.00	510,687.14	532,860.89
Waste generation [kg/capita/year]	409.68	391.16	408.94	381.19	397.74
Waste generation [kg/capita/day]	1.12	1.07	1.12	1.04	1.09
Total MSW generation for whole Belgrade [t/year] (i.e., for all 17 city municipalities)	677,599.65	646,957.67	676,376.54	630,477.95	657,852.95

of the landfill, seasonal changes, regulations and guidelines [37].

Composition of MSW in Vinca Landfill

In terms of morphological composition, the generated MSW can be generally divided into two main clusters: dry waste - waste materials such as plastic, glass, metal, etc., and wet waste that has a relatively high organic content - mainly food and garden waste. The analysis of the morphological composition of MSW in Belgrade was performed for all four seasons, and the obtained analysis results including the average four seasons values obtained by this analysis are shown in Fig. 2 [35].

The data on the composition of MSW that reaches landfill Vinca imply that the largest mass share in the landfilled waste refers to biodegradable waste without garden waste (food waste - all kinds: bread, meat, vegetables, fruits, pastries etc.) with 31.72%, garden

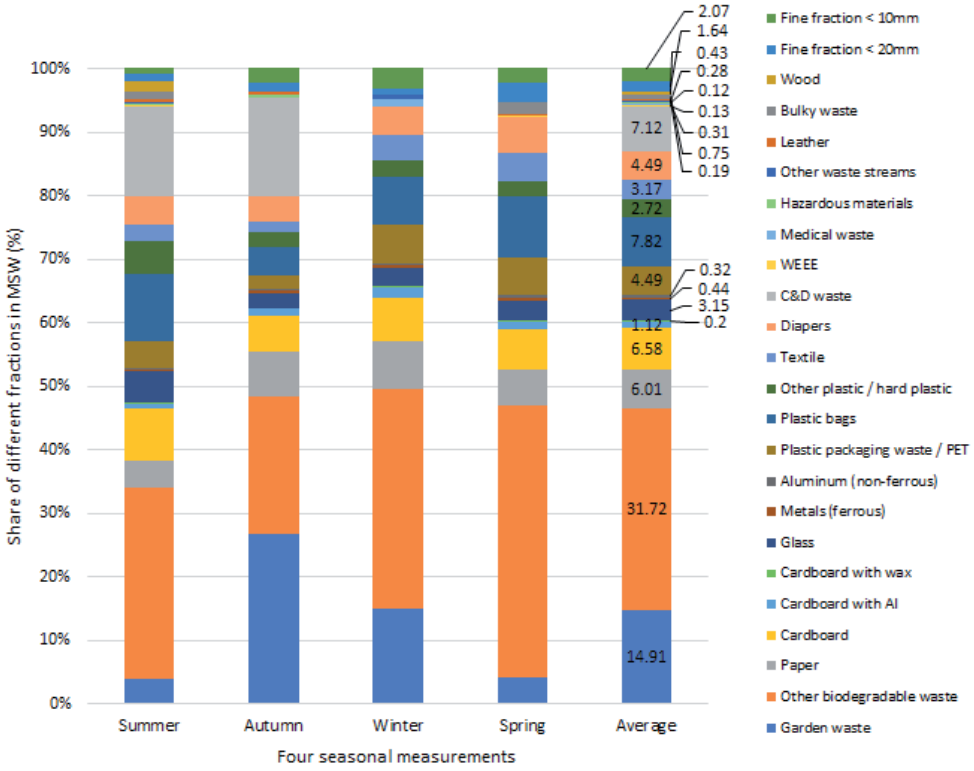

Fig. 2. Composition of MSW for four different seasons and the annual average values [35].

waste with approximately 15%, cardboard 7.7%, paper 6%, textiles 3.17% and wood 0.43%. Also, results show variations of the mass share of waste in relation to the sampling season. Garden waste had the highest percentage in autumn, and the lowest in spring, while the percentage of other biodegradable waste was the highest in spring. Other categories of waste do not show significant differences, except for the construction and demolition waste, which had the highest value in summer and autumn, as a consequence of cleaning and reconstruction of facilities after the floods that hit Serbia in that period.

During the sampling of waste, it was determined that the moisture of the tested samples ranged from 18.66% to 61.12%, while the content of organic matter was in the range from 10.13% to 58.90%. The highest percentage of moisture was measured in the winter, while the highest percentage of organic dry matter was measured in the summer. Obviously, the results of moisture measurements depended on the hydro meteorological conditions, i.e. possible precipitation in the period of several days before the measurement [35].

Perspectives of Vinca Landfill and Energy Production Project

Within the Local Waste Management Plan 2011-2020 [38], the city of Belgrade predicts the remediation of the existing and the construction of a new sanitary landfill in Vinca, as well as the construction of a plant for the production of energy from waste and landfill gas. In 2015, it was decided to implement the project through a public-private partnership, and two years later, a contract was signed with a French-Japanese consortium entrusted with the implementation of the project. The Project [36] includes:

- Closing of the existing landfill site after the remediation and stabilization, with final capping;
- Introducing a management system for MSW on a site of approximately 60 ha, located at the Vinca site. This system will be composed of:
  - An Waste to Energy (WtE) plant, which will generate a combination of electrical and thermal energy;
  - A landfill for the disposal of WtE residues;
  - A sanitary landfill for the share of MSW not processed at the WtE plant;
  - A Biogas Engine Plant (BEP), which will generate a combination of electrical and thermal energy;
  - A treatment facility for the Construction and Demolition Waste (CDW);
  - A leachate treatment plant;
  - Construction of a dam (supporting structure) downstream of the existing landfill;
  - Construction of an electrical infrastructure consisting of 35 KV (cable) and 110 KV (overhead) transmission lines for the purpose of linking the electrical energy produced in WtE and BEP with the transmission grid and providing electricity supply for the Vinca complex;
  - Construction of the hot water pipeline with connection to the heating plant "Konjarnik".

In the southwestern part of the future waste management center Vinca (Fig. 3), on the area of about

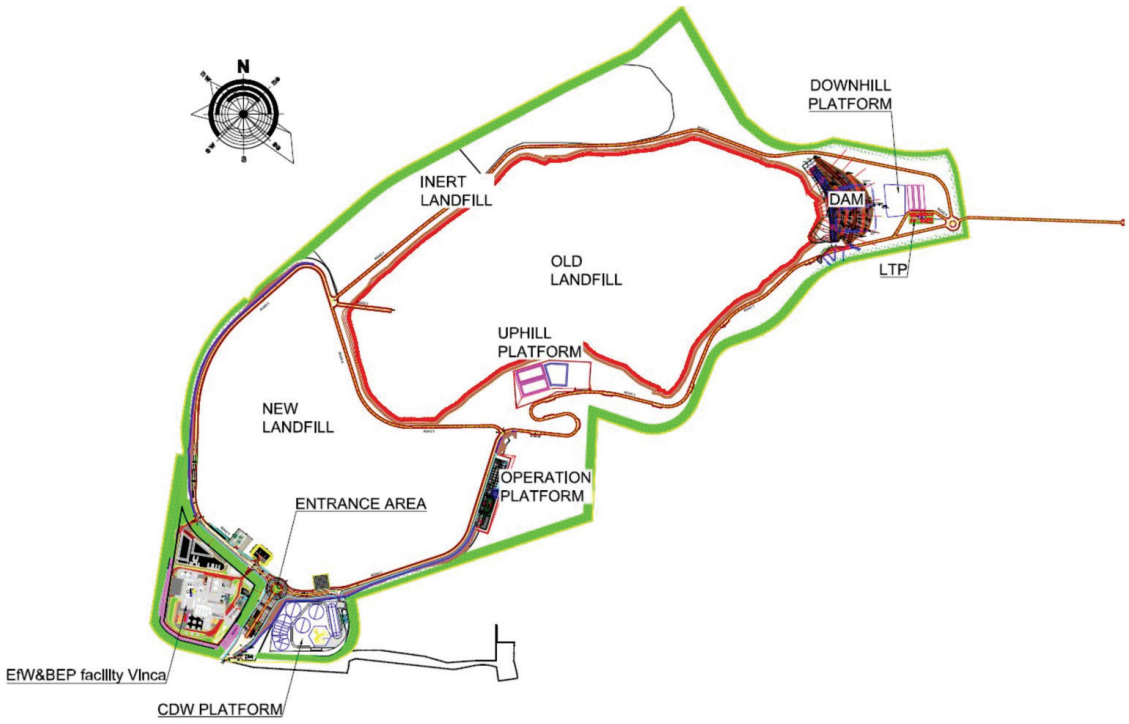

Fig. 3. Waste management complex general layout plan [36].

4.8 ha, as mentioned above, two combined heat and power (CHP) plants are planned, one that uses MSW as fuel (WtE) and another that uses landfill gas as fuel (BEP).

Approximately 510,000 tons of MSW will be directed to Vinca site annually, 340,000 tons to the WtE plant and 170,000 tons to the new sanitary landfill. The WtE plant is designed for the continuous combustion of mixed MSW of lower calorific value (net calorific value) 6-12 MJ/kg. The maximum capacity of the plant is 49.4 t/h of waste with a net calorific value of 6-7.5 MJ/kg, while the nominal capacity is 43.6 t/h (or 340,000 tons/y) when using waste with a net calorific value 8.5 MJ/kg. The WtE plant will have a 103 MW steam boiler and an extraction-condensing steam turbine with an installed capacity of 32 MW electrical and up to 56 MW thermal energy. The WtE plant will generate about 189,652 MWh/y of net electricity fed into the grid with the possibility of the additional 173,611 MWh/y (or 625 TJ/y) of heat distributed into the district heating network.

The BEP plant is designed for continuous combustion of landfill gas that will be collected from the bodies of the old and new landfills, and consists of two CHP modules with a total installed capacity of 3.2 MWe, that will generate around of 26,574 MWh/y of net electricity fed into the grid. Thermal energy produced by the BEP will be used for pre-heating of the WtE combustion air [36].

It should be noted that WtE and BEP plants would annually deliver about 216 GWh of electricity to the Serbian electrical grid, or about 0.55% of gross electricity production. This percentage may not seem large, but it is extremely important because it represents the first significant step in the field of MSWM and WtE for the Republic of Serbia.

According to the timeline for the new Vinca waste management project, new sanitary landfill will start receiving municipal waste by the end of 2021, while the WtE plant should be operational from 2023. Closing the old landfill site after remediation and stabilization is planned to be finished by the end of 2023.

Although construction of waste-to-energy plant and sanitary landfill will significantly improve overall waste management system in Belgrade, there will still be a need for waste collection and transport equipment and infrastructure, especially for achievement of sustainable recycling system and prevention of the loss of secondary raw materials. For increased quantities and purity of secondary raw materials and reduction of the amount of waste going to the waste management center in Vinca, source separation is considered as a crucial precondition. Moreover, separation of recyclable materials at source will need to be implemented in order to meet the requirements of Serbian and EU Legislation (Waste Framework Directive). Besides, adequate schemes and proper infrastructure for collection of special waste streams from households (e.g., bulky waste, WEEE, batteries, tyres, waste oils, C&D waste, etc.) and introduction of home composting for certain number of individual households should be part of future waste management system in Belgrade.

Conclusions

In the last few decades, large quantities of MSW have been stored in landfills in Serbia mainly due to the fact that it is the cheapest waste treatment option. Additional reason for landfilling the waste is the evident absence and poor enforcement of a policy framework for reducing pollution, management and utilization of waste as a potential resource. On the other hand, frequent fluctuations in fossil fuel prices have made projects in the field of waste-to-energy increasingly attractive, since waste can be considered an important resource, from the aspect of energy production.

The first step towards the rational use of MSW as an energy source in waste management center in Belgrade is closing the existing landfill site after remediation and stabilization, together with the introduction of management system for MSW, which includes the construction of a sanitary landfill, WtE plant, BEP plant, leachate treatment plant, etc. The WtE plant will combust 340,000 tons of MSW per year and produce around 190 GWh/y of electrical energy together with approximately 174 GWh/y of thermal energy. The BEP plant will combust landfill gas (extracted from the old and new landfill body) and produce around 26 GWh/y of electrical energy, while thermal energy will be used for WtE needs. The total annual electricity production of these two plants is about 216 GWh, which is about 0.55% of the gross electricity production in Serbia. Also, bearing in mind that MSW and landfill gas are considered renewable energy sources, in this way the share of renewable energy sources in the energy balance of Serbia will increase, which will reduce the use of fossil fuels. While in comparison to the other electricity generation plants, this plant has smaller capacity, it is still an important milestone in the adequate management and production of energy from MSW for transition countries like the Republic of Serbia.

List of Abbreviations

BEP - Biogas Engine Plant
CDW - Construction and Demolition Waste
CHP - Combined Heat and Power
EU - European Union
GDP - Gross Domestic Product
MSW - Municipal Solid Waste
MSWM - Municipal Solid Waste Management
NAPRES - National Action Plan for the Use of Renewable Energy Sources
NWMS - National Waste Management Strategy
PPW - Packaging and Packaging Waste
RDF - Refuse Derived Fuel

RES - Renewable Energy Source
WEEE - Waste from Electrical and Electronic Equipment
WM - Waste Management
WtE - Waste to Energy

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Conflict of Interest

The authors declare no conflict of interest.

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