

POTENTIAL FOR RDF PRODUCTION IN REPUBLIC OF SERBIA

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Abstract: Waste management plays a central role in the transition to a circular economy by closing material cycles, recovering energy from non-recyclable fractions, and reducing emissions through safe treatment and disposal. In the European Union, recycling rates have increased and landfilling decreased, yet municipal solid waste which represents around 27% of total waste generated—continues to grow in both quantity and heterogeneity, posing risks to health and the environment. Energy recovery from MSW is increasingly recognized as essential for achieving EU goals on reducing energy dependence and mitigating climate change, with technologies such as anaerobic digestion, incineration, gasification, pyrolysis, and mechanical-biological treatment producing fuels like refuse-derived fuel and solid recovered fuel. Despite the challenges of complex waste composition, MSW has considerable calorific value, particularly from plastics, paper, textiles, and wood, making it a significant resource for energy production.

Key words: waste, production, fuel, energy, recovery.

INTRODUCTION

Serbia, a South-Eastern European country and candidate for European Union membership since 2014, encompasses a territory of 77,474 km² and has a population of approximately 6.7 million. Waste management represents one of the key environmental challenges in the country, particularly in the field of municipal solid waste (MSW). The collection of MSW in Serbia remains largely based on mixed waste streams, with limited implementation of primary separation practices. Separate collection is most applied to polyethylene terephthalate (PET) and paper and is concentrated in more developed urban areas. Waste collection services are predominantly provided by municipal public enterprises. Recycling performance in Serbia remains low, with the overall recycling rate amounting to 15.5% in 2020, while less than 2% of recycled materials originated from households [1]. These figures underline the structural weaknesses of the current system and highlight the urgent need to strengthen source separation, enhance recycling capacities, and accelerate the development of sustainable waste management practices in line with EU directives and circular economy objectives.

WASTE TO ENERGY POTENTIAL

Waste-to-Energy Potential in Europe and Beyond

Thermal treatment technologies, including incineration, pyrolysis, gasification, mechanical-biological treatment, and biological drying, are widely applied to transform municipal solid waste (MSW) into refuse-derived fuel (RDF) and solid recovered fuel (SRF). In the European Union, waste-to-energy (WtE) plants account for approximately 2.9% of the total electricity generated from renewable energy sources [2].

Within the EU-25, the energy embedded in industrial waste suitable for co-processing already meets around 40% of the demand of energy-intensive industries, with projections suggesting this share could rise to nearly 50% by 2030 [3].

In 2019 alone, European WtE facilities produced primary energy equivalent to 13.8 billion cubic meters of natural gas, which corresponds to roughly 9–10% of the EU's total gas imports. On a global scale, municipal solid waste generation amounts to nearly 2 billion tonnes annually, equivalent to approximately 2.247×10^{15} kJ of energy. Integrated thermal WtE systems can reduce waste volumes by up to 90%, while achieving overall energy efficiencies as high as 60%, particularly when advanced processes such as plasma gasification are applied [4]. At the EU level, system-wide optimization of WtE operations has the potential to increase annual energy recovery from approximately 672 PJ to 872 PJ, representing a 29% improvement through more efficient utilization of existing waste streams.

Waste-to-Energy Development in Serbia

As part of its broader efforts to modernize waste management and harmonize with European Union standards, Serbia has initiated projects to establish controlled waste incineration and energy recovery facilities. A large-scale plant is under construction in Belgrade, while additional facilities are planned for Niš and Kragujevac. These plants are designed to process non-recyclable municipal waste and generate both electricity and heat, thereby reducing reliance on landfilling and supporting diversification of the national energy mix.

Alongside these initiatives, the cement industry has played a prominent role in energy recovery through co-incineration. Cement plants in Beočin and Novi Popovac are already licensed to use alternative fuels such as refuse-derived fuel (RDF), waste tires, and hazardous waste fractions in their kilns, substituting a portion of conventional fossil fuels. This demonstrates the increasing integration of industrial co-processing into Serbia's waste management framework. Plans set out in the Waste Management Program for 2022–2031 envision the establishment of regional RDF production facilities and specialized treatment plants for industrial and medical waste. These developments point to a gradual but meaningful transition towards waste-to-energy solutions, supporting Serbia's long-term goals of reducing landfill dependence, strengthening energy recovery, and aligning with EU climate and circular economy objectives [5].

RDF and SRF production and utilization

Within the European Union, RDF and SRF are increasingly recognized as important substitutes for fossil fuels, particularly in energy-intensive sectors such as the cement industry. Their use contributes both to waste management and to lowering greenhouse gas emissions by diverting waste away from landfills and replacing conventional fuels like coal and petroleum coke [6]. Globally, markets for RDF and SRF are expanding steadily, driven by their role in supporting decarbonization efforts and compliance with climate policies such as the EU Emissions Trading System. Life-cycle studies suggest that, although their production generates some emissions, these are outweighed by the environmental benefits associated with reducing landfill dependency and fossil fuel use. Despite these advantages, the potential of RDF and SRF in Europe has not yet been fully realized, as current generation and uptake remain below what could be achieved. This indicates considerable room for growth, both in terms of increasing the share of waste converted into RDF/SRF and in expanding their application across industries seeking low-carbon energy alternatives.

ASSESSMENT OF THE WASTE POTENTIAL FOR RDF PRODUCTION ON THE STATE LEVEL

According to the most recent data published by the Serbian Environmental Protection Agency (SEPA), the total amount of MSW generated in 2023 reached 3.1 million tons, of which nearly 80% (2.46 million tons) was disposed of in landfills. The national waste management system is currently structured into 27 waste management regions, each intended to serve municipalities with more than 200,000 inhabitants and organized around regional sanitary landfills and associated infrastructure. Despite this framework, only 10 regional sanitary landfills are operational at present.

The separate collection will be improved soon, and the projected quantities of separately collected fractions of municipal waste amount up to 800.000 tons in 2024. The following diagram shows the average morphological composition of municipal waste for the Republic of Serbia. Fractions of municipal waste with potential for RDF production include plastic, paper and cardboard, textile, diapers, bulky waste and other small fractions of municipal waste.

Table 1. Potential of municipal waste for RDF production at the state level

Waste fraction	%	tons/year
Residues from Plastic	11%	99.544,3
Residues from Paper	9%	75.097,3
Textile	15%	130.665,0
Diapers	13%	116.896,0
Others	38%	329.894,0
Bulky waste	13.94%	121.794,0
Total	100%	873.890,5
Percentage of recovery/Total		31%

Based on the average morphological composition of mixed municipal waste in Serbia and the projected quantity of municipal waste that will be generated in Serbia in 2024 (assuming that 25% of the total waste is residual waste), potential for RDF production was calculated. It is estimated that the total theoretical potential for RDF production is approximately around 873.890 tons/year from municipal waste.

From total potential for RDF production from municipal solid waste, 59.758,72 tons/year are communal packaging waste collected within EPR system (Table 3), so the total potential for RDF production from municipal waste is estimated at 858.968,82 tons/year (Reduced by the amount of residual municipal waste 14.921,68 tons/year).

It should be emphasized that each public utility company (PUC) collects waste and dispose of waste in the area for which it is responsible. Thus, the total potential of municipal waste to produce RDF should be taken with reserve, since the available quantities of municipal waste depend on the readiness and ability of the competent PUC to enter for the transfer of municipal waste to a third party.

Potential of packaging waste for RDF production

Next diagram shows the total quantities of packaging placed on the market from 2010-2020.

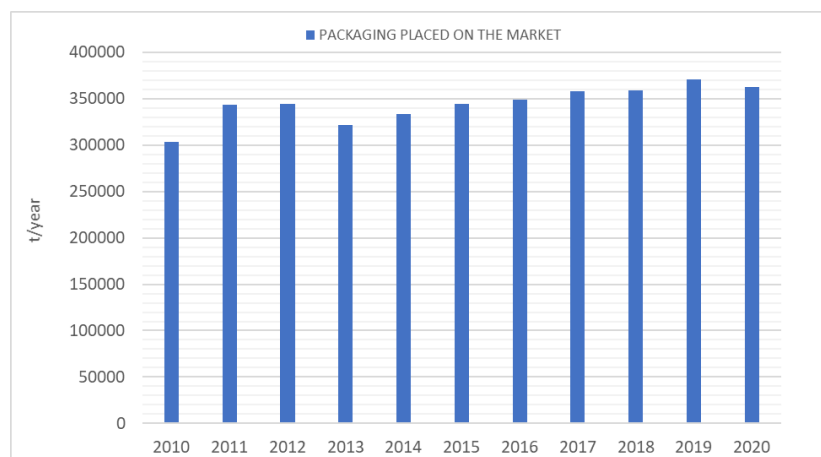


Fig. 1. Quantity of packaging placed on the market of the Republic of Serbia by years [7]

It can be assumed that all packaging placed on the market each year becomes waste in the same year. In the period from 2010 to 2020, the average amount of packaging waste is approximately 344.000 tons per year. The structure of the packaging material is expected to remain on average 20% glass, 27% plastic, 31% paper and cardboard, 4% metal, 18% wood and 1% other. Packaging waste potential for RDF production assessment included only paper/cardboard, plastic, and wood. In practice all packaging waste is not collected and recycled. Collected waste within EPR system, went to recycling and reuse process. In Figure 2 is a trend in the amount of packaging placed on the market and reused packaging waste in the period 2010 – 2020.

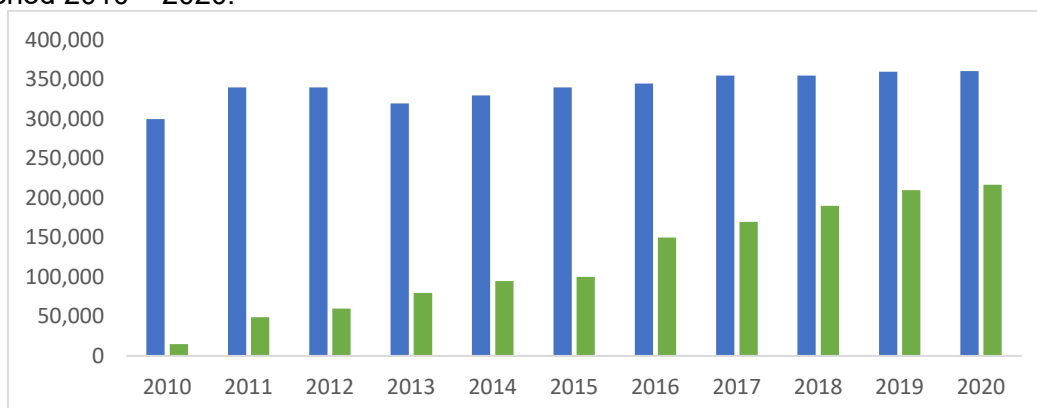


Fig. 2. The amount of packaging placed on the market (blue bar) and reused packaging waste (green bar) in the period 2010 – 2020 [7]

Based on latest report on management package and packaging waste for 2020, Serbia fulfilled the national targets for recycling and recovering of packaging waste whereas through EPR system is collected and treated 186.833 tons/year of packaging waste fractions with potential for RDF production (plastic, paper and cardboard and wood). Therefore, analysis of potential for RDF production from packaging waste is based on residuals (25% residual waste) from treated collected packaging waste (EPR system).

Remaining uncollected packaging waste is landfilled and already included in municipal potential for RDF production. Packaging waste (PW) is generated in communal and non – communal sector (in industry and commercial sector).

Packaging waste from communal sector is collected by PUC in the municipality and it is already included in RDF potential from municipal waste in previous section, while from industry and commercial sector it is collected from PUC or through the EPR scheme. The sources of collected packaging waste within the EPR system are presented in figure 4.

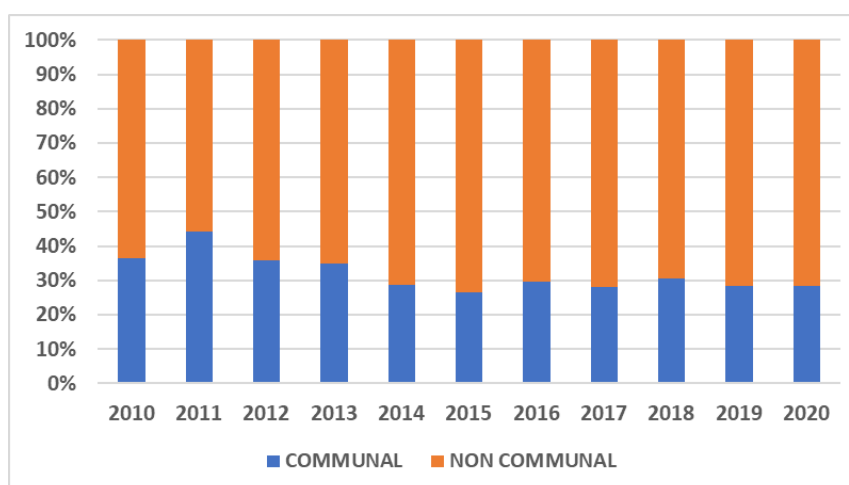


Fig. 4. The sources of collected packaging waste within the EPR % (extended producer responsibility) system [8]

The average share of communal packaging waste in the period between 2010 and 2020 is about 32%, while the share of non-communal packaging waste is about 68% on average. The following table shows the total potential for RDF production from the residual waste after treatment (25% residual waste) in the Republic of Serbia. Total potential for production of RDF from residual communal and non - communal packaging waste (EPR system) is approximately 46.685,5 tons/year. The quantities of secondary wastes, which are generated during waste treatment operations, depend strongly on the level of the waste treatment infrastructure. Secondary waste fractions, that will be generated in the future (if the proposed infrastructure will be realized) could among others include output fractions of the biological part of RDF production plant (up to 60.000 t/year), organic residues and sludges from physical-chemical treatment (up to 12.000 t/year), and digestate from anaerobic digestion. The economic integration and rapprochement of Serbia with the European Union is likely to increase the exports as well as the imports of recyclable wastes like metal wastes, paper waste and plastic waste.

Potential of waste tires for production of RDF

Waste tires are defined as a non-hazardous waste (waste code 16 01 03) and therefore permits for collection, transport, treatment, storing, recovery and disposal, export and import are issued by the Ministry and authorities of Autonomous Provinces, Municipalities or Cities.

Article 49 of the LWM stipulates: "The entity that collects, transports, treats or disposes of waste tires shall hold appropriate permit, maintain, and keep records on quantities of collected and treated waste tires and shall submit such data to the Agency. The Minister shall closely prescribe manner and procedure for waste tires management."

Tires are covered by the Regulation on products that after use become special waste streams upon us thereof ("Official Gazette of RS", No. 54/10). Therefore, production or importation of tires has to be recorded and reported to SEPA on a yearly basis. This report is basis for taxation of a specific fee in line with the principle of extended producer responsibility.

Waste tires are defined as motor vehicle tires (cars, buses, trucks, motorbikes etc.), agricultural and construction machines, trailers, towed machines and so on, after the end of their life cycle, i.e. which owner rejects due to damage, wear and tear or due to other reasons. Tires for passenger cars and trucks represent about 85 % of the total number of produced tires.

The treatment options of waste tires include recycling of waste tires and use for energy purposes. At least 80 % of the waste tires should be recycled and not more than 20 % should be used for energy purposes because of the total quantity of waste tires collected in the previous year.

In accordance with Article 9 of the Regulation on disposal of waste in landfills ("Official Gazette of the Republic of Serbia", No. 92/10) the landfilling of waste tires is prohibited.

There is a substantial production of car tires in Serbia with a high share of export. According to SEPA (2020) 39882.3 tons (e.g. tires from tractors, trucks, buses and fork lifters) of tires were put on the market in Serbia in 2020. This quantity includes the tires produced in Serbia and the tires imported to Serbia in 2020.

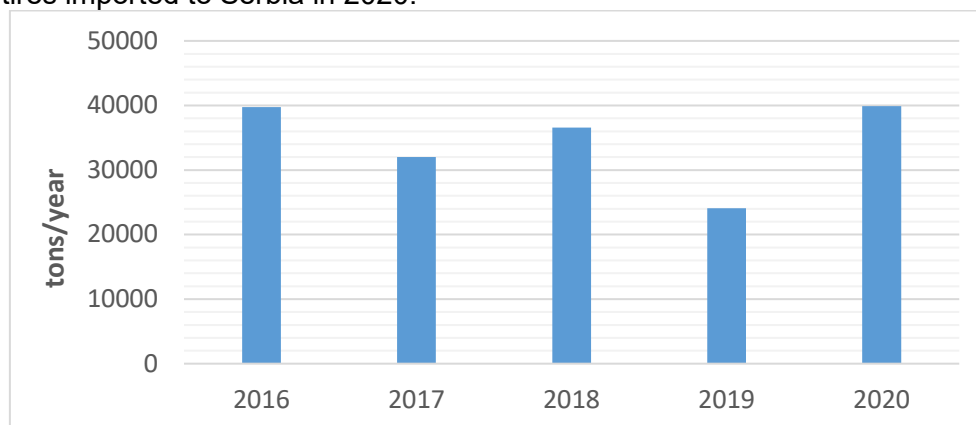


Fig. 5. Quantity of tires put on the market 2016 – 2020 [9]

If 80% of waste tires are recycled, ie about 31.905,84 tons in 2020, in that case about 7.976,46 tons/year can be used to produce RDF. Also, in 2020, about 177 tons of waste tires per year are landfilled, but it can be used for RDF production.

Waste tires are currently used as RDF in cement industry in Serbia. The amount incinerated (R1) in two cement plants was about 13.426 tons. About 27,000 t of waste tires were treated in recycling operations (R5). The installation of civic amenity sites is one tool to reduce the number of tires disposed of illegally. The generation of waste tires closely reflects the development of the car fleet. Based on the waste generation in 2016 in relation to the number of cars in use in Serbia and the predicted development of the car fleet (approx. 1,4% increase per year) a rise of waste generation from 42.175 tons in 2016 to 48.500 tons can be expected in 2024. The quantities of waste tires include also waste from stockpiles, the development of which is hard to predict. The following table summarizes the total potential for RDF production at the state and regional level.

Table 5. The total potential for RDF production from selected waste streams at the state and regional level.

Source	%	tons/year
Municipal solid waste*	94%	858.968,82*
Packaging waste (EPR system)	5.03%	46.686,5
Tires	0.88%	8.153,46
Total	100%	913.808,78

The total potential for RDF production at the state level is about 913.808,78 tons/year, of which approximately 5% refers to packaging waste collected through the EPR system, and rest and the rest represents RDF from residual municipal solid waste collected from PUC. A relatively small amount is represented by waste tires approximately 0.88%, or 8.153,46 tons/year.

CONCLUSION

The assessment of waste streams in Serbia indicates a substantial theoretical potential to produce refuse-derived fuel (RDF) at the national level. Based on current and projected municipal solid waste generation, the total potential for RDF production is estimated at approximately 914,000 tons per year. The largest share derives from residual municipal waste collected by public utility companies, while packaging waste from the Extended Producer Responsibility (EPR) system and waste tires contribute a smaller but still meaningful portion. These figures highlight that a significant fraction of non-recyclable waste could be diverted from landfills and instead utilized as an alternative energy source, supporting both national energy recovery strategies and broader environmental objectives.

However, realizing this potential depends heavily on the development of appropriate waste collection, pre-treatment, and processing infrastructure, as well as effective coordination with public utility companies and compliance with legislative requirements.

The successful integration of RDF production into Serbia's waste management and industrial energy systems could contribute to reducing landfill dependency, decreasing fossil fuel consumption, and promoting circular economy practices. At the same time, careful planning is needed to ensure that RDF utilization does not compete with existing recycling streams, and that environmental and social impacts are properly managed.

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