Bulgarian Chemical Communications, Volume 55, Issue 4 (pp. 441-445) 2023 *DOI: 10.34049/bcc.55.4.5536*

New possibility to locally convert municipal waste into energy

D. N. Kolev*

Institute of Chemical Engineering, Bulgarian Academy of Sciences, Laboratory of Transfer Processes in Multiphase Media, Sofia, Bulgaria

Received: October 14, 2022; Revised: December 05, 2023

This article discusses a technology that enables the use of generated municipal waste near its receipt. This makes it possible to reduce the costs associated with the transport of waste and to reduce the associated greenhouse gas emissions. The use of energy generated by transforming waste into energy benefits the society that generated it. The proposed technology uses municipal waste directly and without the need for pre-treatment outside the plant. The technology provides solutions to avoid possibilities for environmental pollution and allows compliance with all European norms [7]. The proposed installation is designed for treatment of waste generated by a population of 30 to 70 thousand inhabitants.

Keywords: environmental protection, incineration, packed bed columns, gas cleaning, solid waste treatment

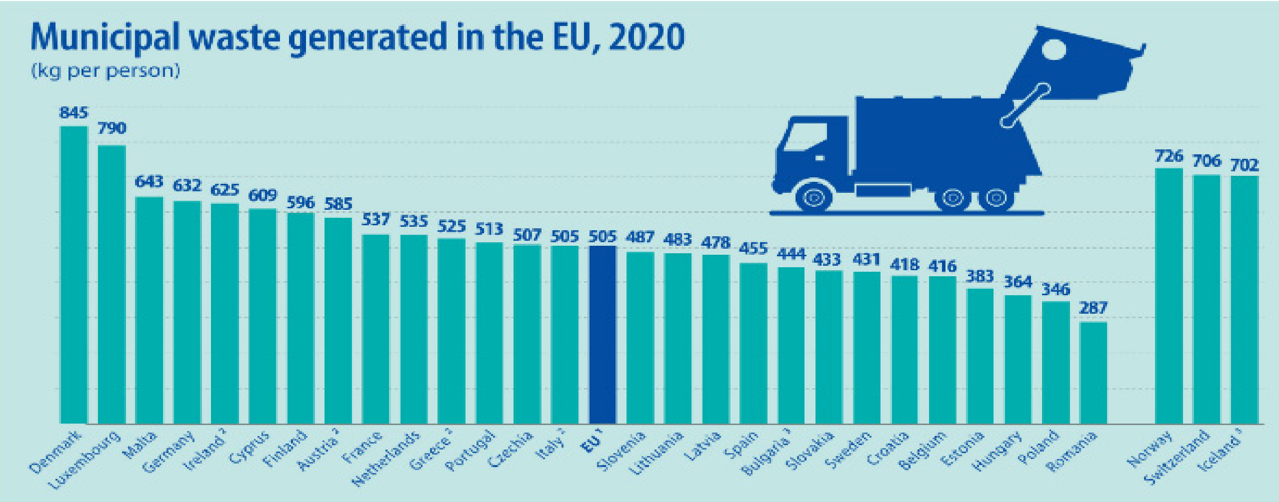

Figure 1. Household waste generated by a person per year in the countries of the European Union, 2020 [1]

INTRODUCTION

With the growing consumption in the recent years, the generation of waste on a European scale has also increased.

As can be seen from Fig. 1, the largest waste production per capita is in Denmark - 845 kg per year per person, and the lowest - 287 kg in Romania. Bulgaria has 444 kg, which is below the European average [1]. Unfortunately, there are no data to clarify the distinction between generation of household waste in cities and in villages.

This article focuses on the state of urban household waste for the city of Sofia. The waste, collected from Sofia, is transported to the Sadinata area near the village of Yana, where a mechanical and biological treatment plant for waste with production of RDF is located [8]. The distance from there to the center of Sofia is 22 km. Bulk density of waste varies from 250-350 kg/m^3, therefore, no more than 10 tons of household waste is collected in one garbage collection truck. The consumption rate of the transport trucks is about 27 l of diesel/per 100 km. On average, 387 467 tons of household waste are delivered to the processing plant annually. According to statistics, the population of Sofia is 1 221 172. If the above chart is considered, the amount of waste produced is 1 221 172 (the population) × 444 (kg waste per person) = 542 200 tons. From the reasoning done, it can be seen that there is difference of 154733 tons. It can be assumed that this amount has been previously separated and submitted for recycling. According to the data of the company that deals with this activity, they have fulfilled their commitments to recycle more than 60% of the packaging put into circulation on the market. The waste separated in the containers of the recycling company is not contaminated with food waste and is

* To whom all correspondence should be sent:
E-mail: d.kolev@iche.bas.bg

suitable for use for recycling.

The transportation of waste from Sofia to the primary processing plant requires 38 746 courses round, in the opposite direction the trucks are empty.

Calculation of required fuel: 38 746 courses × 44 km (both ways; total) × 0.27 l/km= 460 302 litres of diesel fuel. At the price of diesel of 1.53 EUR per litre, this is 706 346 EUR. Let's also calculate the carbon footprint of this transport. The burning of 1 litre of diesel produces 2.67 kg of CO_2, so it is 1 220 t of CO_2 .

What role does the household waste treatment plant play?

It reduces the moisture content of waste;
Obtained recyclate;
Obtained RDF fuel;
Obtained material for direct disposal.

We will briefly discuss the above items separately.

It reduces the moisture content of waste

Reduction of the moisture content of waste is carried out by means of aerobic fermentation of food waste. The food waste turns into earth, giving off heat. The heat is used to heat air that dries the waste. The moisture obtained during the drying process is condensed by means of coolers - water towers. The heat carried by the water vapor is not used, but is emitted into the atmosphere, causing thermal pollution. In this way, a large amount of energy is lost; if it had been used in the combustion process, it would be utilised for heating purposes.

Below is an estimate of the material and heat flows. The data used are for 2020.

Food and green waste in the product entering the plant is 38.9 % with approximately 72% water content [4]. Annually, they are 150 724 t or in dry condition 42 202 t. In the RDF product generated by the plant, the content of food waste is 5.68% and its humidity is 20%, the amount of RDF is 154 652 t. Calculated as a dry substance, this is 7 027 t. When we balance the drying process, as well as losses in the various separation processes, 64 984 t is obtained. Their energy evaporated 102 000 000 kg of water. If we equate the calorific value of dry food waste to carbohydrates (1 kg- 4000 kcal, 16.74 MJ), the energy carried in dry waste is 140 698 452 000 kcal (589 076 GJ). Evaporation of 1 kg of water requires about 700 kcal (2.93MJ). If we assume that the dry waste is burned in a cauldron with an efficiency of 80% (conservative assumption), 160 798 tons of water can be evaporated with this energy. The amount of energy that would be saved, recalculated as diesel (1 l diesel - 10 000 kcal, 41.86 MJ) is 4 115 860 kg (6 297 265 EUR). Its carbon footprint is 10 989 t of CO_2, respectively. At time of writing, the price of carbon emissions fluctuates between 70-90 EUR per ton, as shown in Fig. 2. For the calculation a significantly lower value of 50 Euros is assumed resulting in 549 467 Euros.

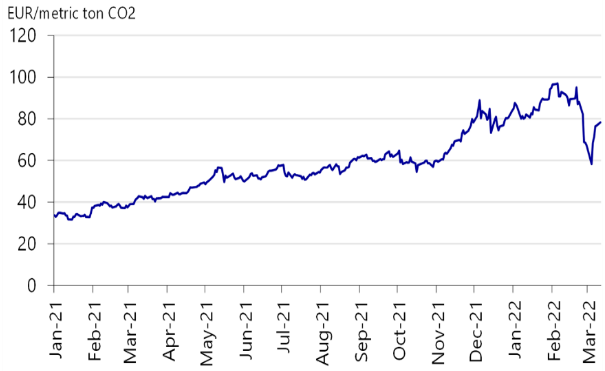

Figure 2. Average tender price of quota emission in Euro/t.CO_2 [2]

If a combustion installation is used, the shown effect could increase up to two times as the evaporated water will condense and heat the heating water.

Obtained recyclate

The annually received recyclate is 36 997 tons, which is 10.5% of the input material. In the process of separation, several products are separated. The price the Metropolitan Municipality receives for them is given below:

Mixed plastics 18 146 t - bid price 1.82 EUR/t
Glass 4628 t - bid price 1.68 EUR/t
Paper and cardboard 5908 t - bid price 3.82 EUR/t
Ferrous metals 6296 t - bid price 10.23 EUR/t
Nonferrous metals 578 t - bid price 306.9 EUR/t

Based on the above prices, the total revenue of the plant from separation of products is 305 343 EUR. Below is a figure showing the international average exchange prices in the European Union for waste products.

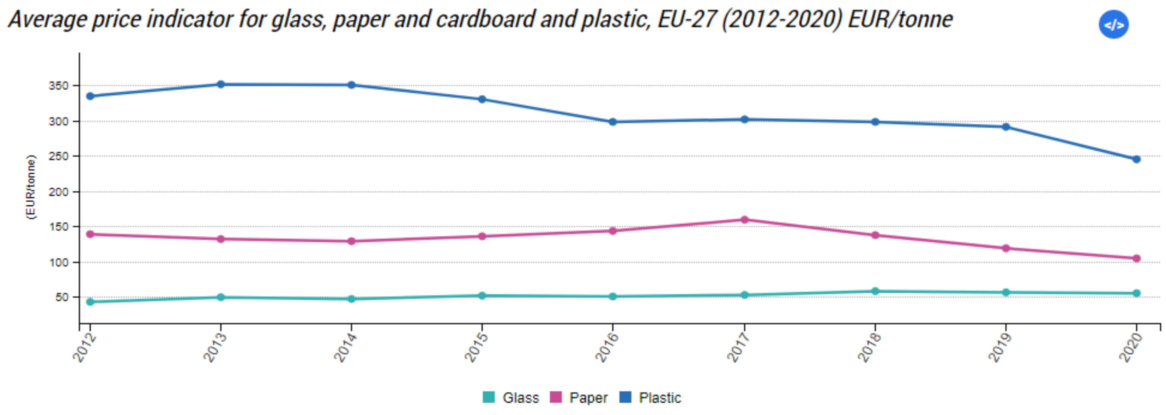

Figure 3. Average European prices of separated waste materials by year [1]

The values for 2020 are: glass 65 EUR, paper 120 EUR, plastics 270 EUR.

Calculating from the quantities received in the processing plant according to the data from Fig. 3, the result is 5 905 960 EUR. These prices are lower than the usual trade prices, mostly due to the contamination of food waste [9].

Obtained RDF fuel

The amount of RDF obtained is 154 652 t with an average calorific value of 3000-4000 kcal/kg (12.5-16.7 MJ). It should be noted that household waste is treated as a partially renewable source of energy. At the moment, there is no RDF incineration plant built in Sofia, which is why the processing plant is overflowed with material. According to data from the Ministry of Environment and Water, the plant currently pays 15 to 25 EUR per ton to licensed companies that can use it. Only 50 000 t are disposed of in this way, the rest is landfilled.

In the future, a waste incineration plant on the territory of the Sofia district heat and power station is planned to be built, which will be able to burn the entire amount of RDF produced by the plant and produce electricity, as well as heat the water for central heating.

The distance from the processing plant to the heat and power station site of Sofia is 23 km. And here, as above, we will calculate the fuel consumption for transportation of the waste, as well as its carbon footprint. The amount of fuel is 15 465 × 46 × 0.27 = 192 075 litres of diesel. Carbon footprint 192 075 × 2.67 = 512.8 t CO_2.

Obtained material for direct disposal

The amount of disposed waste is 52 072 tons. This amount is about 14 % of the supplied material. It most likely contains materials that, when burned, would give off an additional amount of heat. By burning this waste, its quantity would also be significantly reduced.

Health considerations

In the separation plant, all the household waste of Sofia is being mixed. Before the Covid-19 pandemic, this did not attract the attention of the specialists in the field, but now is already treated with caution. Dissociation and separation of waste is done mostly manually. Workers performing these activities are exposed to great risks, that is why burning of municipal waste without this treatment step is advantageous for the workers' health.

The alternative

Below in Figure 4 is presented a new technology (successfully patented [3]) for using urban household waste as a raw material to obtain electrical energy and heat for heating needs. The installation can be located in residential neighborhoods, so that the distance from which the waste is delivered does not exceed 3-5 km. To date, this technology has not been implemented. The feasibility studies for the implementation of the technology provided us with evidence that the necessary territory required for the construction of the waste treatment plant is a little over 4 000 m^2. The installation is intended for treatment (waste-to-heat process) of 50-100 tons of household waste per day without being previously processed. The energy characteristic of Sofia waste is 1300 kcal/kg (5.4 MJ) with a moisture content of 40% [4].

Operation processes

The arriving truck discharges the waste into a receiving bunker. After the bunker, the waste passes through a separation line where the following takes place: the bags are broken open, then waste passes through a scale and magnetic separator, and from there it is delivered into a shredder. After being so separated it is delivered into a day bunker or into a line stand-by bunker. The stand-by bunker has a capacity to take waste for 15 days.

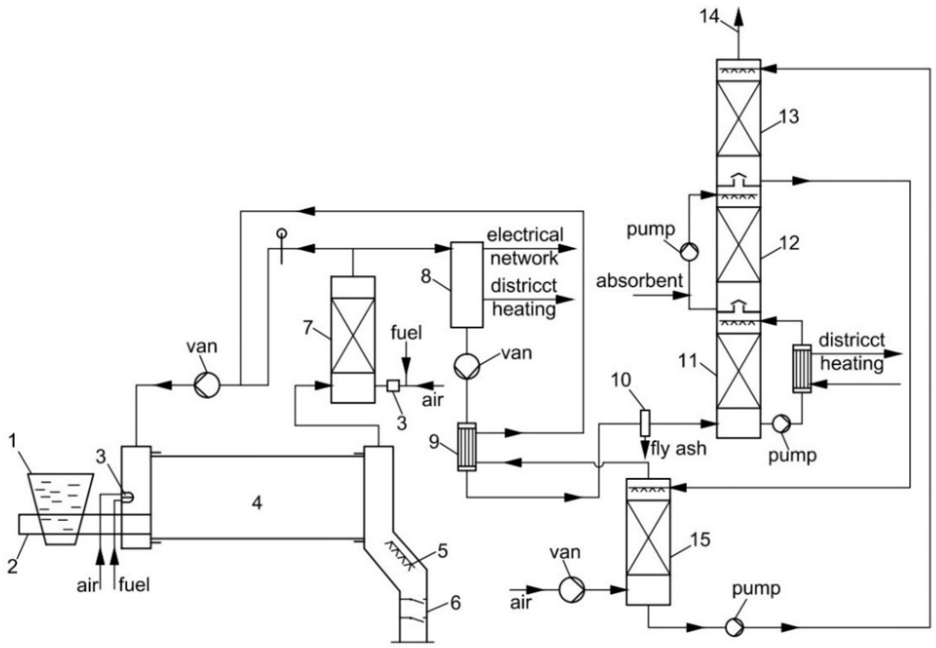

Figure 4. Installation for incineration of urban household waste. 1. day bunker, 2. feed auger, 3. burner, 4. rotary kiln, 5. water nozzle, 6. bottom ash extractor, 7. post combustor, 8. utilization unit, 9. recuperation unit, 10. beg filter, 11. contact economizer I, 12. absorber, 13. contact economizer II, 14. chimney, 15. direct heater and humidifier

From the daily bunker, the waste is delivered to the rotating combustion chamber (rotary kiln). The downtime therein is around 30 minutes. The length of the rotary kiln is 15 m. The temperature maintained in the combustion chamber is about 850 ºC. On the initial start of the plant, a liquid or gaseous fuel burner shall also be used to provide the required temperature. During the process, when the temperature in the combustion chamber starts decreasing, the burner is automatically turned on to maintain it. The bottom ashes generated from the incineration are removed from the combustion chamber, being pre-cooled with water. The device does not allow uncontrolled air entering into the process when removing the ash. The flue gases generated are supplied to a post-combustor where a burner maintains a temperature of 1100 ºC. The post-combustor is designed as a packed bed column, which makes it possible to maintain the temperature profile therein constant. The gas downtime in the post-combustor is more than 2 seconds. If necessary, a burner can keep the temperature in the post-combustor constant. After the post-combustor, the gases are separated into two streams. One stream goes to a recovery unit, where they are cooled down to 500 ºC. They then are sent to a recuperation unit, where they heat the air for the incineration process, and they are cooled down to 200 ºC, temperature of the wet thermometer is 79.1 °C. Next, they pass through a bag filter to separate the ash carried over with the gases. Thus, cooled and mechanically purified gases are delivered into a contact economizer [5] - direct water heat exchanger, where they indirectly heat the district heating water up to 75 ºC. Then they enter an absorber for their chemical treatment. The absorber uses sodium carbonate solution. In the process are formed: sodium fluoride, sodium chloride, sodium sulfite, sodium sulfate. When sodium carbonate is depleted, the solution is replaced. After the absorber, the gases enter a second economizer. There they heat the water, which in turn heats and humidifies the air for the incineration process. Flue gases leave the plant through a flue duct fully meeting the highest environmental requirements.

The second stream of gases is being mixed with the heated and humidified air and with a temperature of about 700 ºC is delivered to an entry of the rotary kiln.

The recovery unit is a Rankine cycle turbine [6], where electricity and heat are generated in the form of hot water for district heating purposes.

Advantages of the proposed installation

Small in size, operated almost automatically, no environmental pollution. The Rankine cycle turbine used to generate electricity operates at low temperatures with organic oils used in a closed cycle.

From an energy point of view: If we consider the installation as a black box, where the input is waste with high humidity and air with an external temperature necessary for combustion, and the output is flue gases with a temperature of 30-35 ºC, with waste water that underwent heat treatment (the water that was part of the waste), slag from the combustion process, a solution of salts from gas cleaning. The rest is electrical energy and heat for heating purposes.

CONCLUSION

The construction of RDF separation and production plants is economically, technically and environmentally unfeasible. Renewable resources such as green and food waste are wasted instead of replacing fossil fuel energy.

The development of technologies should lead to the best use of the energy capacity of urban household waste.

By building several installations at different sites, it will not be necessary to build additional heat accumulator systems, since the heating network itself plays this role. The distances over which waste is transported will be reduced and the carbon footprint of its transport reduced.

Construction of local installations [3] for incineration of waste should be located next to the district heat and power stations. In Sofia, there are 4 large heat and power stations - Zemlyane HPS, Sofia HPS, Lyulin HPS and Sofia Iztok HPS; there is enough free space on their territory for the construction of the proposed installations.

REFERENCES

1. www.ec.europa.eu/eurostat
2. C. Stet, P. Ruiz, *RaboResearch - Economic Research* https://economics.rabobank.com/publications/2022/march/high-eu-carbon-prices-are-structural-inaction-no-option/ (2022)
3. D. Kolev, R. Lyutskanova, *Patent BG* 66232 B1 (2006)
4. I. Ganev, *Energy Forum,* 425 (2008)
5. D. Kolev, *Bulg. Chem. Commun.,* **35** (3), 153 (2003).
6. Turboden ORC units 2008 Turboden-wood Energy Information Day1 www.scribd.com/document/43070228/Turboden-woodEnergyInformationDay1
7. D. Kolev, 8th International Conference on Energy Efficiency and Agricultural Engineering, 2022, DOI: 10.1109/EEAE53789.2022.9831282
8. www.spto.bg
9. Public auction of Sofia Municipality (Bulgaria) 04-so-2022 from 26.05.2022.