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# Implementacija Hijerarhije upravljanja otpadom - Prevencija kao imperativ održivosti

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**Apstrakt:** Ovaj rad predstavlja komparativnu analizu količina komunalnog otpada generisanog u zemljama EU i zemljama koje nisu članice EU. Pozitivna iskustva razvijenih zemalja pokazuju da se najbolji rezultati postižu kada se obrati pažnja na lokalne specifičnosti, uz poštovanje nacionalnih strateških opredeljenja za svaku vrstu otpada posebno. Sagledano je postojeće stanje, analizirana praksa i tumačeni značajni strateški dokumenti i propisi. Na osnovu toga predložena su racionalna i izvodljiva rešenja koja obuhvataju širok spektar mera za unapređenje upravljanja otpadom, počev od smanjenja nastajanja otpada na izvoru, odvojenog sakupljanja, reciklaže ili drugih metoda oporavka materijala iz otpada, pa do pouzdano i ekološki održivo konačno odlaganje otpada. Takođe, preporučene su neophodne prateće mere, edukativne i promotivne aktivnosti, kao i praćenje uspostavljenog sistema. Cilj rada je da prikaže trend rasta/opadanja količina generisanog komunalnog otpada u zemljama članicama Evropske unije i u zemljama koje to nisu. Benchmarking analiza je pokazala trend smanjenja količina generisanog komunalnog otpada u razvijenim zemljama, što jasno ukazuje na uspešno implementirane strategije koje se zasnivaju na hijerarhiji otpada.

**Ključne reči:** Upravljanje otpadom, strategije, ciljevi, generisanje otpada, hijerahija upravljanja otpadom

# Implementation of the Waste Management Hierarchy - Prevention as an imperative of sustainability

**Abstract:** This paper presents a comparative analysis of municipal waste amount generated in EU memeber and non EU member countries Positive experiences from developed countries show that the best results are achieved when attention is paid according to local specificity, while respecting national strategic determinations for each type of waste separately. The existing situation was reviewed, practice was analyzed and significant strategic documents and regulations were interpreted. On this basis, rational and feasible solutions were proposed, which include a wide range of measures to improve waste management, starting with the reduction of waste generation at the source, separate collection, recycling or other methods of recovering materials from waste, and ending with reliable and environmentally sustainable final disposal of waste. Also, necessary accompanying measures, educational and promotional activities, as well as monitoring of the established system were recommended. The paper focuses on municipal waste, which amounts generated per year present one of the most problematic in every country. The aim of the work is to show the trend of growth/decrease in the amount of municipal waste generated in European Union, member countries and in countries that are not. The benchmarking analysis showed a trend of decreasing amounts of municipal waste generated in developed countries, which clearly indicates successfully implemented strategies based on the Waste Hierarchy.

**Keywords:** waste management, strategy, goals, waste generation, the Waste Hierarchy

# 1. Introduction

There are uncountable correlation between the economic growth on waste generation and environmental degradation. Increase in waste amount has a direct consequence on human health and environment, and contribute to climate change (Uddin et al., 2017). Among the largest economies in the EU are France, Italy, and the Netherlands, with GDPs of around 15 trillion Euro GDP (SRD, 2024). Although in the EU the generation of municipal solid waste has continuously increased over the last two decades, 392million tonnes of municipal solid waste were generated (Gardiner and Hajek, 2020). Developing countries in Europe, non EU members adopt policies and EU Directives related to waste management to reduce the amount of municipal waste that has been disposed without any pre - treatment. In order to decrease adverse effects to citizens, these countries still a need a framework with stakeholders and government to achieve good MSW management, considering the barriers and goals on this path (Batista et al., 2021).

The prerequisite of good waste management system is to understand how much waste is generated and the types of waste, to apply the appropriate management methods. Since Circular Economy enter, there was notable increase in waste management performance in EU, namely Germany, Italy and Neatherlands. The implamation of a good practice reflect in decrease of waste generated and increase in recycling rate. Recently the EU member countries (France, Germany, Italy, the Netherlands, and United Kingdom) great interest in enhancing a full CE, showed great results (Chioatto and Sospiro, 2023).Thus, in two decades the average EU-28 landfilling rate felt from 64% to 23%, recycling rate rose from 17% to 47% and incineration rate almost doubled from 67 kg per capita to 136 kg per capita (Eurostat, 2019). The most supprising results report Netherlands with 511 kg per capita 50% recycled and landfilling near to zero.

However, in developing countries, such as Bosnia and Hercegovina, main barrier are unclear legal regulations and guidelines on waste management because there are no unique goal so that every BiH entity act in one way in order to achieve good MSWS (Novarlić and Đurić, 2024). The North Macedonia still struggles to achieve waste management goals, but economic situation prevent this country to do better results. With 55 ilegal dumpsites, urgent actions are needed. Thankfully, EU support will provide 75% of waste to be recycled and recovered and about 25% of waste will be disposed on sanitary landfills (Sapurica et al., 2021). The aim of this paper is to present waste sustainability throught the Waste Hierarchy, prioritising the prevention rather the disposal of municipal waste.

### 1.1. Waste management in Serbia

The local waste management plan must be harmonized with the Regional Waste Management Plan. It is necessary to implement the Plan with the municipal competent body for environmental protection as well as in cooperation with other bodies responsible for business operations, finance, environmental protection, urban planning and with representatives of companies, enterprises, associations and professional institutions (Čarapina and Mihajlov, 2011). All performed analyzes and proposed solutions are based on the National Waste Management Strategy, the Law on Waste Management, other legal and by-laws of the Republic of Serbia that treat or relate to this issue, as well as EU Directives related to waste management. Waste management is organized in a way that does not pose a danger to human health and the environment. If a legal entity, i.e. a natural person, handles waste contrary to this law and as a result there is a danger or risk to human health and the environment, the Republic of Serbia takes urgent measures to protect human health, the environment, i.e. surface and underground water, air, soil, plant and of the animal world (Todić and Grbić, 2013).

The National Waste Management Strategy is a basic document that provides conditions for rational and sustainable waste management at the level of the Republic of Serbia. Key steps include strengthening existing and developing new measures to establish an integral waste management system, further integration of environmental policy into other sectoral policies, acceptance of greater individual responsibility for the environment and more active public participation in decision-making processes.The basic characteristics of an effective waste management system include a whole series of incentive measures that reduce waste generation, encourage waste separation at the source, recycling and other methods of utilizing materials and energy from waste, and sustainable final waste disposal. The general goals of the National Waste Management Strategy are rational and sustainable exploitation of natural resources and environmental protection (Drobnjak et al., 2019). It is necessary to create a

sense of responsibility for dealing with waste at all levels, ensure recognition of the problem, provide accurate and complete information, promote principles, incentive measures and partnership between the public and private sectors in waste management.

## 2. Methodology

Comparative analysis of the waste that is deposited in Serbia and the observed EU countries, in compliance with the EU Directives and the metodological framework for waste management. The analytical framework is built around the Waste Hierarchy, emphasizing the prevention of waste generating known as the most preferable rather than disposal options. In this paper, benchmarking analysis is used to show how successful implementation of all EU legislations influence waste generation as the best option in waste management. The analysis includes data obtain from eurostat that reflects the best available and necessary methods applied in developed and developing countries. The aim of the work is to show the trend of growth/decrease in the amount of municipal waste generated in European Union member countries and in non-member countries. The benchmarking analysis is to show a trend in amounts of municipal waste generated, which will clearly indicates successfully implemented strategies based on the Waste Hierarchy.

## 3. Municipal waste generation a prerequisite for sustainability

The goal of the European Union and its policy on waste does not include the treatment of waste flows, but puts the prevention of waste generation in the foreground. Now we have a new direction, which is prevention and reuse as the most priority options. Recycling is an option that requires energy and creates side streams (i.e. waste). Waste prevention deals with the causes of waste. Therefore, reducing waste means less consumption of resources, energy and money. On the other hand, the generation of large amounts of waste is correlated with a positive factor of economic growth. The goal is to make decisions that will have the impetus to separate economic growth from waste generation (Bartley, 2014). Table 1. shows municipal waste generated.

Table. 1. Generation of municipal waste display in t/year

| TIME | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 | 2020 |
|---|---|---|---|---|---|---|---|---|---|
| Belgium | 47,611,87 | 55,312,65 | 42,703,09 | 56,578,50 | 51,053,71 | 55,004,25 | 59,339,50 | 64,271,52 | 64,116,01 |
| France | 287,816,61 | 303,409,0 | 334,109,3 | 343,543,11 | 333,137,7 | 313,680,0 | 311,674,9 | 331,209,3 | 299,133,14 |
| Croatia | 7,095,390 | 4,654,857 | 3,951,007 | 3,085,119 | 3,490,259 | 3,594,324 | 5,192,628 | 5,368,960 | 5,816,804 |
| Italy | 133,671,65 | 147,560,3 | 172,379,3 | 150,084,20 | 145,440,0 | 148,993,1 | 154,120,8 | 162,364,9 | 164,925,33 |
| Hungary | 23,296,427 | 20,987,35 | 16,278,58 | 16,194,824 | 15,609,90 | 16,054,08 | 15,480,93 | 17,826,74 | 16,574,433 |
| Netherlands | 90,311,710 | 94,030,86 | 98,194,61 | 116,658,98 | 116,339,0 | 127,529,9 | 135,889,8 | 140,116,1 | 120,117,17 |
| Austria | 52,007,223 | 53,324,70 | 54,978,78 | 45,326,715 | 46,979,20 | 54,596010 | 59,964,08 | 64,351,95 | 67,618,927 |
| Bosnia and Herzegovina | : | : | : | : | 3,510,633 | 5,532,069 | 6,113,730 | 6,733,444 | 6,743,515 |
| North Macedonia | : | : | 1,356,025 | 2,178,056 | 7,793,775 | 2,145,815 | 1,367,854 | 1,119,783 | 1,066,420 |
| Serbia | : | : | : | 22,454,746 | 40,545,39 | 35,653,28 | 31,734,84 | 35,747,91 | 47,289,509 |

Source: Eurostat

Based on the available data, the overall trend of growth in the amount of waste generated in the observed countries can be clearly observed. France has the highest growth trend until 2018, and from 2020 it shows a downward trend due to the methodological approach of reducing generation at the

source. Hungary has the most responsible behavior in this sense, where social responsibility and the implementation of options for recycling, reuse and reducing generation have given results. Good responsibility in this regard is also shown by North Macedonia, where in continuity since 2012 there has been a peak drop in the total waste produced, which leads us to the conclusion that the options in waste management are being implemented.

### 3.1 Waste generated in Serbia

The initiatives aim to encourage the population to have a more responsible attitude towards waste and to deal with waste in a sustainable way, such as reducing waste at the source, reusing waste, recycling, energy utilization of waste and disposing of waste in a safe manner. Although the Republic of Serbia still has no obligation to implement the goals of the EU directives related to comprehensive waste treatment, the gradual inclusion of these requirements and the establishment of an integral waste management system is one of the priorities of the Government of Serbia and all relevant strategic documents (Todorović, 2020). Of extreme importance for further consideration is the fact that the National Waste Management Strategy is a document that recommends, rather than obligates, certain technical solutions, technological procedures, locations and concepts.

**General objectives of the national waste management strategy**

The national waste management strategy aims to ensure:

- protection and improvement of the environment,
- protection of human health and sustainable development i
- controlled use of natural resources.

**Specific objectives of the national waste management strategy**

Special objectives of the National Waste Management Strategy are divided into short-term and long-term objectives:

- **Short-term objectives:**
  - Harmonize national waste management regulations with EU legislation;
  - Adopt national plans for individual waste streams;
  - Develop regional and local waste management plans by 2014;
  - Increase the number of residents covered by the waste collection system to 75% by 2014;
  - Develop a system of primary waste selection in local governments;
  - Build 12 regional waste management centers by 2014 (regional landfills, recyclable waste separation facilities, biological waste treatment facilities and transfer stations in each region);
  - Establish a hazardous waste management system (build central regional hazardous waste warehouses and start construction of facilities for physical and chemical treatment of hazardous waste by 2014);
  - Establish a management system for special waste flows (waste tires, spent batteries and accumulators, waste oils, waste vehicles, waste from electrical and electronic products);
  - Establish a medical and pharmaceutical waste management system;
  - Establish a system of animal waste management and adopt a regulation;
  - Encourage the use of waste as an alternative fuel in cement plants, iron plants and thermal power plants, in accordance with the principle of the waste hierarchy;
  - Rehabilitate existing landfills that pose the greatest risk to the environment and "black spot" locations from historical hazardous waste pollution.
- **Long term objectives:**
  - Introduction of separate collection and treatment of hazardous waste from households and industry;
  - Build 12 regional waste management centers - regional landfills, recyclable waste separation facilities and transfer stations in each region;
  - Provide capacities for burning (incineration) of organic industrial and medical waste;
  - Strengthening of professional and institutional capacities for hazardous waste management;

- Achieve a rate of reuse and recycling of packaging waste (glass, paper, cardboard, metal and plastic) at 25% of its quantity;
- Establish a management system for construction waste and waste containing asbestos.

The national waste management strategy to be implemented, the first step is to determine the amount of waste generated (t/year). Table 2. presents amount of municipal waste generated as well as planned network of regional waste management centers in Serbia.

Table 2 – Planned network of regional waste management centers

| | **Local self-government, the bearer of the activity of the construction of the regional waste management center** | **Municipalities that make up the regional center** | **Number of inhabitants of the region** | **Amount of waste t/year** |
|---|---|---|---|---|
| 1. | Sombor | Apaktin, Kula, Odžaci,Bač | 230252 | 59925 |
| 2. | Subotica | Bačka Topola, Kanjiža, Mali Iđoš,Senta,Novi Kneževac, Čoka | 266195 | 86759 |
| 3. | Novi Sad | Bačka Palanka,Bački Petrovac, Beočin,Vrbas,Srbobran,Temerin | 510552 | 192236 |
| 4. | Kikinda, Novi Bečej | Ada, Žitište, Nova Crnja, Bečej | 200853 | 46856 |
| 5. | Pančevo | Opovo | 138165 | 54937 |
| 6. | Vršac | Bela Crkva, Alibunar, Plandište | 111057 | 33781 |
| 7 | Zrenjanin | Sečanj, Kovačica, Titel | 193358 | 67522 |
| 8. | Inđija | Irig, Ruma, Sremski Karlovci, Pećinci, Stara Pazova | 211016 | 74315 |
| 9. | Sremska Mitrovica | Šabac, Šid, Mali Zvornik, Loznica, Bogatić, Krupanj | 397239 | 85046 |
| 10. | Beograd | Voždovac, Vračar, Grocka, Savski venac, Sopot, Stari grad, Surčin, Čukarica | 1421987 | 796338 |
| 11. | Valjevo | Ub, Osečina, Lajkovac, Mionica, Ljig, Koceljeva, Vladimirci, Barajevo, Lazarevac, Obrenovac | 382330 | 88085 |
| 12. | Smederevo | Požarevac, Kovin, Veliko Gradište, Golubac | 250762 | 63670 |
| 13. | Petrovac | Malo Crniće, Žabari, Kučevo, Žagubica | 90989 | 9315 |
| 14. | Lapovo | Velika Plana, Smederevska Palanka, Rača, Despotovac, Batočina, Svilajnac | 179003 | 37712 |
| 15. | Kragujevac | Arađelovac, Topola, Gornji Milanovac, Knić | 319088 | 86663 |
| 16. | Jagodina | Paraćin, Ćuprija | 160077 | 44137 |
| 17. | Užice | Bajina Bašta, Požega, Arilje, Ivanjica, Čajetina, Kosjerić, Čačak, Lučani, Ljubovija | 378568 | 91536 |
| 18. | Nova Varoš | Priboj, Prijepolje, Sjenica | 116168 | 19462 |
| 19. | Zaječar | Bor, Negotin, Majdampek, Kladovo, Knjaževac, Boljevac, Sokobanja | 271445 | 31839 |
| 20. | Pirot | Dimitrovgrad, Bela Palanka, Babušnica | 100033 | 21631 |
| 21. | Kraljevo | Vrnjačka Banja. Novi Pazar, Raška, Tutin | 296722 | 57097 |
| 22. | Kruševac | Trestenik, Varvarin, Rekovac, Ćićevac, Brus, Aleksandrovac | 363821 | 91388 |
| 23. | Niš | Gadžin Han, Svrljig, Ražanj, Doljevac, Aleksinac, Merošina | 363821 | 91386 |
| 24. | Prokuplje | Žitorađa, Kuršumlija | 98220 | 18068 |

| | | | | |
|---|---|---|---|---|
| 25. | Vranje | Preševo, Bujanovac, Trgovište, Vladičin Han, Surdulica, Bosilegrad | 229552 | 49977 |
| 26. | Leskovac | Lebane, Bojnik, Medeđa, Vlasotince, Crna Trava | 233612 | 55906 |

Source: Edited by the author

The table clearly shows that cities generate higher amount of municipal waste compared to towns. Therefore, options to prevent and then to manipulate with waste must be applied.

### 3.2. Waste management options that need to be implemented

The concept of hierarchy indicates that the most effective solution for the environment is to reduce waste generation. Where it is not practically applicable, products and materials can be used again, either for the same or a different purpose, through recycling or composting, or for obtaining energy (Tsekeris and Anastassakis, 2022). Only if none of the previous options provide a suitable solution should the waste be disposed of at the landfill.

**REDUCTION OF WASTE AT THE SOURCE**

Reduction must be considered every time a decision is made about the use of resources. The reduction must be designed through the entire life cycle of the product, i.e. already in the design phase, through production, packaging, to transportation and placement of the product. Consumers should also actively participate in waste reduction by purchasing products with less packaging. The government should be the bearer of the waste reduction policy.

**RE-USE**

Some products are specifically designed to be used multiple times. There are good reasons to reuse products:

- Savings in energy and raw materials
- Reduction of disposal costs
- Reduction of costs for producers and consumers.

**RECYCLING**

Recycling achieves extremely significant technical, ecological and economic effects: reducing the amount of waste that must be disposed of in landfills, reducing the consumption of basic raw materials, saving energy, extending the lifetime of existing landfills, significantly slowing down the process of depletion of natural resources, etc.(Beke and Jovanović, 2013). The reasons for the need for increased utilization of waste are multiple:

- knowledge about limited natural resources and the need for rational use of what is available;
- regulations on environmental protection define stricter conditions for waste disposal, so it is necessary to reduce the volume of waste disposed of at the landfill by recycling;
- difficulties in securing locations for new landfills point to recycling as one of the possibilities of reducing the need for new landfills.

Typical components of the waste recycling system in order to use materials and separate useful waste are:

- separation of various components at the source of waste generation - from households, shops, institutions, collection on the street or in centers where recyclable waste is collected (primary recycling);
- separation of recyclable materials from the total mass of waste in facilities for the separation of recyclable waste;
- preparation of separated recyclable materials on lines for baling (paper, plastic), pressing (metal), grinding (glass).

## COMPOSTING

Composting is defined as the rapid, but partial, decomposition of moist, solid organic matter, food waste, garden waste, paper, cardboard, using aerobic microorganisms and under controlled conditions. The product is a useful material, similar to humus, which does not have an unpleasant smell and can be used as a soil conditioner or as a fertilizer.

In principle, composting is carried out in two levels: ¬ collection and separation of organic components (kitchen waste and garden waste) for composting in compost fields or in special plants (most often regional type); ¬ promotion of independent composting "in your own yard" through education and establishment of small composting bunkers. Considering the EU Landfill Directive and the ban on dumping biodegradable waste in landfills, composting has gained importance as an alternative treatment option for biodegradable waste (Bugarski et al., 2018)

## ANAEROBIC DIGESTION

Decomposition of the organic, biodegradable part of solid waste into gases with a high methane content can be achieved through anaerobic decomposition or anaerobic fermentation in a reactor. After the fermentation of organic waste separated at the source, the rest of the fermentation (digestate) is normally treated aerobically to compost (Ugrinov and Stojanov, 2010). In this way, the final result of waste fermentation is in most cases similar to aerobic composting. The decomposition process produces biogas, compost and water.

## OTHER WASTE TREATMENT SYSTEMS

The national strategy for waste management also considered other options for waste treatment from among new technologies, namely: incineration, pyrolysis, gasification, plasma process, waste as fuel, physical-chemical waste treatment (Mélypataki, 2022).

## DISPOSAL OF WASTE IN LANDFILLS

There are three types of waste disposal landfills: o non-hazardous waste disposal landfills; o landfills for disposal of inert waste; o landfills for disposal of hazardous waste. Landfills dispose of certain types of waste for which the landfill was designed. For the disposal of non-hazardous waste, the so-called sanitary landfills, which represent a sanitary-technically organized area where waste is deposited as a material that is generated on public surfaces, in households, in the process of production, i.e. work, in circulation or use, and which does not have the properties of hazardous substances and cannot be processed, i.e. rationally use as industrial raw material or energy fuel.

Landfills intended for the disposal of hazardous waste are designed with special technical requirements. Hazardous waste that is disposed of at such landfills must be pre-treated in accordance with regulations. Landfills are necessary in any chosen treatment option, because there is always a part of the waste that must be disposed of.

## STRATEGIC DIRECTIONS OF WASTE MANAGEMENT

The main strategic directions of waste management are as follows:

- Institutional framework for waste management;
- Decentralization and distribution of responsibilities;
- Institutional requirements and sectoral integration;
- Planning and management methods;
- Involvement of the private sector;
- Technical aspects, which include:
    - Prevention and reduction of waste generation;
    - Reuse and recycling;
    - Improving the organization of collection and transport;
    - Reliable waste disposal.

**KEY PRINCIPLES OF WASTE MANAGEMENT**

There are a number of key principles that must be taken into account when establishing and implementing the National Waste Management Strategy, namely:

- The principle of sustainable development.
- Principle of proximity and regional approach to waste management.
- Precautionary principle.
- The polluter pays principle
    - The principle of hierarchy in waste management.
- The principle of applying the most practical options for the environment.
- The principle of producer responsibility.

**REGIONAL SANITARY LANDFILLS**

Regional landfills are landfills for non-hazardous waste. A landfill for inert waste can be built within the center in accordance with regulations. Only the following can be disposed of at the non-hazardous waste landfill:

- communal waste after separation;
- non-hazardous waste of any origin that meets the criteria for receiving waste at the landfill for non-hazardous waste;
- stabilized and non-reactive, previously treated hazardous waste, if the limit values of pollutants in the eluate do not exceed the limit values for non-hazardous waste.

The landfill is equipped with a system for collecting landfill gases. If the use of gas is not economical, it should be burned on site. The regional landfill, in addition to other elements, must also have a plant for the treatment of leachate. The plant for the separation of recyclable waste is placed in the area next to the landfill. A technological line is being set up for automatic or manual separation of waste (Marković et al., 2023). Separated recyclable materials are baled or pressed and further transported to plants that recycle such waste. A composting or anaerobic digestion facility may include complete mechanical-biological waste treatment, or only aerobic waste treatment in a facility or compost field located next to a landfill.

**TRANSFER STATION**

Transfer stations are places for temporary storage, preparation and transshipment of waste destined for transport to the regional waste management center. Considering the concept of waste management in the Republic of Serbia, the flow of waste includes its passage through the transfer station. A transfer station is a place where municipal waste is unloaded from a waste collection vehicle, inspected with possible separation of bulky waste, kept for a short time, loaded into larger vehicles and transported to a regional center for further treatment (Ugrinov et al., 2021). Locations of existing municipal waste dumps that need to be rehabilitated according to approved remediation projects can also be used as transfer stations.

CENTERS FOR SEPARATE COLLECTION OF RECYCLABLE WASTE are places intended for sorting and temporary storage of special types of waste. These centers play a significant role in the overall waste management system because they serve as a link between the local self-government unit and citizens, authorized collectors and persons who perform treatment. Locations for setting up centers that ensure the implementation of measures for separate waste collection should be provided by local self-government units. Primary waste selection will be gradually introduced. A constant campaign and education of citizens about the need and importance of primary selection is needed

## 4. Conclusion

Integral waste management involves looking at waste from the moment of its creation, minimization, through collection, transport, treatment and disposal. If one wants to achieve a sustainable waste management system, it is necessary to consider all options for waste treatment. The decision on choosing the most suitable option for treatment is made through the analysis of the life cycle of the waste, including the characteristics of the environment and the location where the waste is generated. The concept of the hierarchy of waste management indicates that the most effective solution for the environment is to reduce the generation of waste.

However, where further reduction is not practicable, products and materials may be reused, either for the same or a different purpose. If this possibility does not exist, the waste can be further used through recycling or composting or to obtain energy. Only if none of the previous options provide a suitable solution should the waste be disposed of at the landfill. The waste hierarchy is a prominent element of waste management policy and has the basic task of promoting waste minimization, favoring recycling and reuse rather than landfilling.

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