CRACOW UNIVERSITY OF ECONOMICS

MUNICIPAL WASTE MANAGEMENT IN MODERN CITIES

Krzysztof Wąsowicz, Stanisław Famielec, Marcin Chełkowski

Toruń 2020

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INTRODUCTION

How can we change our lives by changing the cities? The reasoning behind such a question is diverse[1]. The most important aspect shall be the progress of urban planning – urbanized areas cover only 2% of Earth, but urban population increases by 60 million inhabitants on a yearly basis. The second most important reason is the fact that urbanized areas consume 75% of the energy produced globally, which translates to over 80% of carbon dioxide emissions[2]. The third premise is the growing significance of households in economics and economic practice, since they are the oldest entity of national economy that participate in production and consumption processes[3].

Cities are the source of wealth but also the source of social, economic, spatial and environmental problems. Cities are favored by the type of development which provides work places and tax income[4]. The increase of population in cities is accompanied by the growing importance of aspects regarding esthetics, climate, or city lifestyle. The relations between economy, the society and the environment constitute the subject of interdisciplinary studies the result of which is the discovery of models and concepts for a sustained urban development. They involve a cooperation between local authorities and communities

[1] Such questions constitute the scientific problem of the book by Ch. Montgomery, a renowned Canadian specialist in modern urban planning, history and development of cities: Ch. Montgomery, *Miasto szczęśliwe. Jak zmieniać nasze życie, zmieniając nasze miasta*, Wyd. Wysoki Zamek, Cracow 2015.

[2] M. Kustra, *Znaczenie inwestycji w rozwoju smart cities na przykładzie Barcelony*, in: *Inwestycje w zrównoważonym rozwoju miast*, ed. A. Szelągowska, CeDeWu, Warsaw 2017, p. 41.

[3] A. Bauer-Nawrocka, *Konwergencja i nierówności dobrobytu ekonomicznego gospodarstw domowych w krajach Unii Europejskiej*, "Gospodarka Narodowa", 2018 issue 3, p. 104.

[4] Ch. Montgomery, *Miasto szczęśliwe. Jak zmieniać*…, op. cit., p. 362.

in order to restore and plan cities and districts in a manner favoring social equality and personal safety, as well as to stimulate innovation and employment. It is considered necessary to limit the negative outcome of urbanization and use of chemical substances that pose a hazard to human health and the environment, i.a. by limiting the processing of waste, recycling of waste, and by promoting more effective use of water and energy[5].

In the city, everything is intertwined – tangible processes and objects with intangible ones, economic elements with social elements, all of them in the geographical and public plain, with households being the main entities. The indispensable characteristic regarding the functioning of households[6] is the fact that they produce municipal waste which gives rise to macroeconomic, social, and political problems. The individual production of said waste by inhabitants of households requires a collective service (management) and the task has become a public utility service. Maintenance of cleanliness and order is one of the obligatory tasks of communes[7]. They safeguard cleanliness and order within their territory and conceive conditions necessary to maintain them. They cover all the real property owners within their territory with a municipal waste management system.

The processes of generating and managing municipal waste (collection, transport, processing of waste, along with the supervision over such activities) is referred to as waste management. Waste management is a complex, interdisciplinary concept which also covers activities within the scope of planning and implementation of undertakings and technologies. Municipal waste management has been – especially since 2013 – the subject of research and scarce scientific publications. Their dominant notion has been the perspective of the commune,

[5] Among important documents in this matter, it is worthwhile to mention Projekt Europa 2030. Challenges and chances. Report for the European Council prepared by the Reflection Group on the future of the EU, called Agenda 2030. See A. Szelągowska, *Miasta w świetle koncepcji zrównoważonego rozwoju*, op. cit., pp. 23-30.

[6] It is more and more often highlighted that municipal waste is not only generated by inhabitants but also by the industry (e.g. production of packaging, clothes, food), by promoting and offering the customers disposable goods (sometimes without a choice of a different offer, in the pursuit for profit, by limiting information on the outcome and by using unfair competition).

[7] Since 1 July 2013, the rules for municipal waste management in Poland have been provided for in: Act dated 13 September 1996 on maintaining cleanliness and order in communes, Polish Journal of Laws 1996 issue 132 item 622 with further amendments, Act dated 14 December 2012 on waste, Polish Journal of Laws 2013 item 21 with further amendments.

while the presented economic and financial aspects regard the capacity of households to increase expenditures on municipal waste management services[8].

This monograph has outlined the attempt to analyze waste management, particularly the processes of municipal waste management in the perspective of cities (contrary to the administrative – communal and regional approach towards those processes presented so far).

The theoretical goal of the monograph has been to identify and organize the economic, technological and legal grounds of municipal waste management systems in cities. The empirical aim of the monograph has been to collect data and describe the condition of municipal waste management in certain Polish and foreign cities, as well as to assess such management in selected cities from the perspective of effectiveness.

The general thesis of the elaboration is the view that: the efficiency of managing a city is ensured by establishing and functioning of a comprehensive and successful municipal waste management system. The first detailed hypothesis states that in the case of large cities such economy is more effective; large companies, in the in-house (communal) mode in form of commercial companies, are more efficient and effective than other types, including private establishments. The second detailed hypothesis has been formulated as follows: the effects of municipal waste management in foreign cities are reflected in recovery and recycling ratios that are superior to those in Polish cities, especially those served by private entities.

The assessment of municipal waste management in cities has been conducted through the criterion of effectiveness – understood as achieving general financial and operational relations in communes and companies. On the basis of the above, an effectiveness ranking for analyzed companies and communes in Poland has been elaborated.

The research on the effectiveness of municipal waste management has applied an original method of assessing the integrated effectiveness – such a method facilitates analyzing the dependency between operating indicators regarding the condition of municipal waste management in the commune and

[8] The following should be mentioned: *Wydatki na usługi komunalne w strukturze wydatków mieszkańców gmin – ocena w układzie regionalnym*, ed. Z. Grzymała, SGH, Warsaw 2015. Apart from fees for municipal waste management, this publication has analyzed rental fees, charges for local transport, utility fees.

the financial characteristics: income of the commune from the fee for managing municipal waste, balance sheet characteristics and output data of companies.

The monograph has included a broader analysis of the following scientific problems:

- Development of theoretical grounds for municipal waste management in cities, with a particular focus on its behavioral nature, management hierarchy for waste, chains and installations within the municipal waste management systems, and the standards and norms governing them (Chapter 1).
- Elaboration of a database and information to describe municipal waste management in Poland and in deliberately selected Polish cities – Cracow, Białystok, Koszalin, and Nowy Targ (Chapter 2).
- Elaboration of data and information to describe municipal waste management in deliberately selected foreign countries: Germany, Czech Republic, and Austria (Chapter 3).
- Calculation of the effectiveness in 38 communes (with the intent to achieve a representation of every voivodeship), including 63 companies that are involved in municipal waste management in those communes. In order to measure the effectiveness for companies that operate in differently organized municipal waste management systems, a multi-criteria ranking was utilized (Chapter 4).

The monograph has been based on analyses of source material in the field of economics and technology as well as chemistry of municipal waste management processes, on the scientific achievements of the authors[9] and scientific experiments that have already been conducted by the authors[10] for several years.

[9] Examples: J. Famielec, S. Famielec, *Pomoc państwa i zamówienia in house w procesach i zakładach przekształcania odpadów komunalnych*, in: *Pomoc publiczna. Doświadczenia wybranych sektorów gospodarki*, ed. M. Kożuch, Fundacja Uniwersytetu Ekonomicznego w Krakowie, Cracow 2017; J. Famielec, S. Famielec, *Restrukturyzacja sektora gospodarki odpadami komunalnymi*, in: *Restrukturyzacja sektorów gospodarki i przedsiębiorstw*, ed. J. Famielec, M. Kożuch, Fundacja Uniwersytetu Ekonomicznego w Krakowie, Cracow 2017; J. Famielec, S. Famielec, *Integracja nauk ekonomicznych, technicznych i chemicznych na rzecz rozwoju zrównoważonego*, "Ekonomia i Środowisko", 2016 issue 3(58); M. Chełkowski, J. Famielec, *Taryfy w gospodarce odpadami komunalnymi fantazją czy koniecznością?*, "Przegląd Komunalny", 2016 issue 11 (302); J. Famielec, S. Famielec, *Ekonomiczne i techniczne uwarunkowania procesów spalania odpadów komunalnych*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu", 2016 issue 454.

[10] Among numerous resources, the following should be mentioned: *Diagnoza efektywności przedsiębiorstw gospodarki odpadami komunalnymi ze szczególnym uwzględnieniem in house*, ed. J. Famielec, K. Wąsowicz, Chair of Industrial and Environmental Policy of the University of Economics, Cracow 2018.

Chapter 1.

THEORETICAL GROUNDS OF MUNICIPAL WASTE MANAGEMENT

1.1. The meaning and conditions of municipal waste management

In light of the act on waste[11], **waste** stands for every substance or object which the owner disposes of, intends to dispose of, or is obligated to dispose of. This category also comprises of **municipal waste**, which has been defined in the act on waste as waste generated in households, excluding end-of-life vehicles, as well as waste free from hazardous waste and originating from other producers of waste which, due to its nature or contents, is similar to waste generated in households.

Green waste forms an unusual group – it is understood as municipal waste composed of parts of plants originating from maintenance of green space, gardens, parks, cemeteries, as well as marketplaces, excluding street-cleaning residues.

The act on waste and relevant regulations also provide the definitions for a set of terms connected with waste management. For the purpose of this monograph, the following should be quoted:

[11] Act dated 14 December 2012 on waste, Polish Journal of Laws 2013 item 21 with further amendments.

- **Producer of waste** should be understood as any person whose activity or existence leads to generation of waste (original producer of waste) and any person who conducts the initial processing, mixing, or other actions that result in changing the characteristics or content of such waste. The producer of waste generated as a result of provision of services within the scope of construction, demolition, renovation of structures, cleaning services for containers or other equipment, as well as cleaning, maintenance and repairs is the entity that renders the service, unless the service agreement stipulates otherwise.
- **Waste management** stands for generating and managing waste. **Managing waste** is understood as collecting, transporting, processing waste, including the supervision over such activities, as well as i.a. further handling involving waste disposal facilities.
- By **collecting waste**, one should understand accumulation of waste before it is transported to waste processing facilities, including preliminary sorting plants that do not change the basic character and content of waste.
- **Waste processing** refers to processes of recovery and disposal, including preparations preceding recovery and disposal.
- **Recovery of waste** stands for any process the main result of which is the use of waste for advantageous purposes by replacing other materials that would otherwise be employed to serve a particular function, or for any process as the result of which waste is prepared to serve such a function at a particular plant or in general economy. A non-exhaustive list of waste recovery processes has been provided in Attachment no. 1 to the act on waste.
- **Recycling** stands for a specific type of recovery as a part of which waste is re-used in production of goods, materials or substances used for the original purpose or otherwise. Recycling includes re-processing of organic material (organic recycling), but it does not cover energy recovery or re-processing into materials that will be used as fuels or for backfilling.
- **Waste disposal** is a process that is not considered as recovery, even if it involves recovery of a substance or energy as part of a secondary result. Waste disposal processes, listed in Attachment no. 2 to the act on waste, include, among others, storage at landfill sites and thermal conversion of waste.

- **Thermal conversion of waste** means processes of incineration of waste through oxidation and other processes, including pyrolysis, gasification, or plasma process. Waste conversion is only allowed at incineration plants or co-incineration plants under rules provided for in detailed regulations.
- **Waste landfill site** is a building structure intended for storage of waste.

Depending on the source of generation, waste has been divided into groups, sub-groups and types and has been assigned codes the complete list of which has been specified in the Waste Catalogue Ordinance[12]. Municipal waste along with selectively accumulated fractions form 'group 20' in the catalogue. In this group, we distinguish, among others, a type of waste called "unsorted (mixed) municipal waste" designated with code 20 03 01.

Waste, including municipal waste, is a macroeconomic problem – it incorporates an integral element of production processes, consumption, investments and, consequently, establishing and breakdown of the GDP. Waste is present throughout the whole cycle of economic and social life – starting from obtaining and using renewable and non-renewable resources, consumption of other natural processes, waste contributes to mismanagement of resources and the chance to protect them and to fulfill a testament for future generations. Generation of waste is unavoidable, yet susceptible to limitations through changes in the mindset, the style and the structure of consumption (counteracting and prevention).

Waste is an objective and an inevitable phenomenon in management; it can be used as a source of secondary raw materials and fuels; in this sense, it can bring economic and social benefits. Except for hazardous waste or waste that is, due to its content or properties, considered as: harmful, toxic, corrosive, carcinogenic, mutagenic, etc.

Municipal waste is distinguished by source of generation. The source is a household inhabited by local community members living and managed by local government units. Sources of generation are closely related to the consumption processes of natural persons, whereby such processes occur not only at households, but also as part of industrial activity, services, commercial activity,

[12] Ordinance of the Minister of Climate dated 2 January 2020 on waste catalogue, Polish Journal of Laws 2020 item 10.

functioning of institutions. Thus, municipal waste is one of the groups of waste, just like industrial waste, hazardous waste, sewage, healthcare waste, etc.

Waste management is a complex, interdisciplinary concept that also covers activities within the scope of planning, implementation and of undertakings and technologies[13].

Waste management refers to issues and processes, such as[14]:

- regulations, any instructions, norms and standards within the scope of production and utilization of waste,
- waste management plans at local, regional, national and interstate level,
- reporting concerning production and management of waste, i.a. breakdowns covering amounts of generated waste, its composition and types,
- issues connected with determination of properties, composition, toxicity, etc. of waste and assessments and forecasts as to the amount and type of produced waste,
- collection and transport of waste,
- processing of waste, methods and technologies to recycle waste, recover raw materials and energy or to utilize them,
- aspects connected with waste disposal through storing it at landfills, technologies for waste storage, landfill management, etc.

Waste management may be considered by means of processes and subject matters[15]. In the case of waste management processes, prevention of waste production is preferred, while waste storage is the least desired solution. The subject matter setting differentiates various types of waste, such as municipal waste, waste generated by households, as well as waste generated by business entities, mainly service providers, if such waste is similar to the one generated at households in terms of composition and characteristics and does not contain hazardous waste.

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[13] H. Folmer, L. Gabel, H. Opschoor, *Ekonomia środowiska i zasobów naturalnych*, Wydawnictwo Krupski i S-ka, Warsaw 1996.

[14] Further reading: J. Famielec, *Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym and Pomoc państwa i zamówienia in house w procesach i zakładach przekształcania odpadów komunalnych*, in: *Pomoc publiczna. Doświadczenia wybranych sektorów gospodarki*, ed. M. Kożuch, Fundacja Uniwersytetu Ekonomicznego w Krakowie, Cracow 2017.

[15] *Zarządzanie środowiskiem*, ed. B. Poskrobko, PWE, Warsaw 2007, p. 210.

The institutional conditions of municipal waste management include institutions of local and central administration, as well as legal standards, such as:

- commune,
- municipal council,
- district sanitary inspectorate,
- voivodeship environmental protection inspectorate,
- real property owner,
- entity (a municipal company or an entrepreneur) collecting waste,
- minister of the environment, minister of economy, minister of finance, minister of climate,
- waste law, environmental law, tax law, tax ordinance, act on product fee and deposit fee,
- local government act,
- antitrust law,
- permission to render services and conditions for granting such permissions,
- required conditions, e.g. EU standards.

The processes of gathering, transport and management of municipal waste are not only of public but also of market characteristics. The market is a set of mechanisms that allows the contact of manufacturers (e.g. waste producer, recycling entity) with purchasers – recipients of waste, secondary raw materials.

Entities within the system of municipal waste management should cooperate and have an agreement[16]. This should ensure social and financial advantages (including profits) for most or all of participants in the system as well as make address the shortcomings of the market and limit any ineffectiveness. It requires establishing proper institutional structures with the involvement of the state and regional governments. These structures are subject to various determinants and are integrated into many areas of social and economic life, which has been depicted in Diagram 1.

[16] N. Stern, *Globalny ład*, Wyd. Krytyki Politycznej, Warsaw 2010, p. 230.

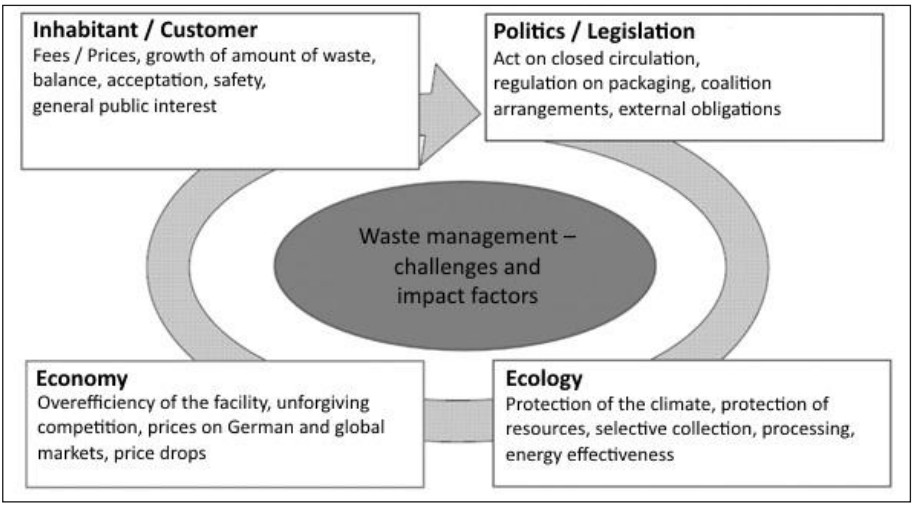

Diagram 1. Determinants of waste management

Source: own analysis.

Directive 75/442/EEC introduced a management hierarchy for waste (including municipal waste), which became binding for all member states of the European Union (Diagram 2). The hierarchy recommends the desired sequence of actions concerning waste management – the action that is higher in the hierarchy shall always be preferable: prevention, preparation to reuse, recycling, other recovery methods, e.g. energy recovery, disposal. In Polish legislature, the principles for the hierarchy of handling waste have been acknowledged in the act on waste[17].

Bearing in mind the management hierarchy for waste, storage is the least acceptable, extremely unfavorable, and even prohibited – in the case of some groups of waste – solution concerning waste management. Development of waste management technology mainly strives for preparing waste for recovery, particularly for recycling. In order to achieve that, the European Union imposes standards regarding the minimum levels of recycling and preparation for reusage of municipal waste that member states must comply with. The next action in this hierarchy is forwarding waste for energy recovery. By energy recovery

[17] Further reading: J. Famielec, S. Famielec, *Restrukturyzacja sektora gospodarki odpadami komunalnymi*, in: *Restrukturyzacja sektorów gospodarki i przedsiębiorstw*, ed. J. Famielec, M. Kożuch, Fundacja Uniwersytetu Ekonomicznego w Krakowie, Cracow 2017.

one should mainly understand all thermal (incineration) processes that allow recovery of thermal energy.

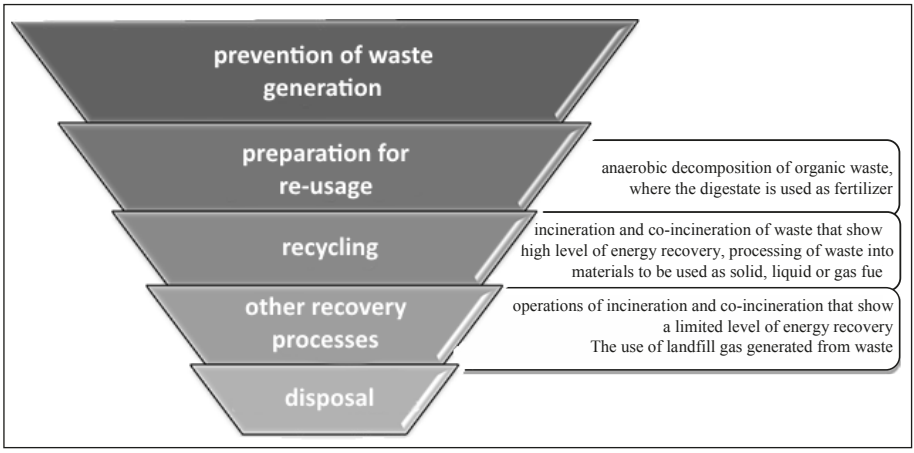

Diagram 2. Management hierarchy for waste, along with the position of measures of processing waste into energy

Source: own analysis based on the Communication of the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, The meaning of processing waste into power in a closed economy, Brussels 26.01.2017, COM 2017, p. 34.

1.2. Managing municipal waste – technical aspects

The technical aspects of the municipal waste management system cover the following activities:

- collection of waste,
- transport of waste,
- processing of waste.

Processing of waste may also generate additional waste (of similar or completely different nature than the processed waste) that requires further management. Moreover, in order to maintain the technical efficiency of the municipal waste management system, it is of crucial importance to ensure proper exploitation of plants employed in processing of municipal waste, as well as to perform environmental control over potential emissions from such plants to the environment. For instance: in the case of a municipal waste incineration plant, it is essential to ensure collection of the generated thermal energy and electricity, properly manage

the waste involving slag, fly ash and deposits from exhaust cleaning processes, as well as to control the emission of pollution in exhaust gases.

The amendment to the act on waste in 2013[18] introduced the rule of regional waste management to the Polish legislative system, defining the term of region of waste management and plants intended to render services in regions, the so-called **Regional Municipal Waste Processing Facilities** (Polish abbreviation: RIPOK). The **region of management** of municipal waste is the area of neighboring communes that have, in total, at least 150,000 inhabitants, and it is handled by regional facilities[19].

In order to become a RIPOK facility, a waste management plant had to have a capacity that was sufficient to accept and process waste from an area inhabited by at least 120,000 people; it also had to comply with the BAT requirements or ensure:

- mechanical and biological processing of mixed municipal waste and the possibility of extracting fractions that can be fully or partially recovered from mixed municipal waste, or
- selective processing of accumulated green waste and other bio-waste and using such waste to produce products with properties of fertilizers or other plant growth stimulators (with proper parameters set in separate regulations), or
- storage of waste generated in the mechanical and biological processing of mixed municipal waste and storage of sorting residues from municipal waste in a capacity that allows accepting waste for a period not shorter than 15 years and in an amount not lower than the amount generated in the facility for mechanical and biological processing of mixed municipal waste.

The special status of a supra-regional municipal waste processing facility, pursuant to the act on waste, was granted to municipal waste incineration plants – they should have capacities sufficient to accept and process mixed municipal waste accumulated from an area inhabited by at least 500,000 people and comply with the BAT requirements[20].

[18] Act on waste in the version published in Polish Journal of Laws 2013 item 21, Art. 35, sections 5 and 6.

[19] Act on waste in the version published in Polish Journal of Laws item 21, Art. 35, section 5.

[20] Art. 35, section 6a of the Act on waste, introduced with the act dated 15 January 2015 on amendment to the act on waste and certain other acts, Polish Journal of Laws 2015 item 122. Currently (after the amendment in 2019), the section has been repealed.

Changes in legal regulations in 2019[21] canceled the regional character and repealed articles regarding RIPOK facilities, introducing the term of **municipal plant** – it is a facility to process unsorted (mixed) municipal waste and residue from processing of such waste, specified in the lists published by marshals of voivodeships in the Public Information Bulletin, meeting the BAT requirements, and which provides:

1) mechanical and biological processing of mixed municipal waste and the possibility of extracting fractions that can be fully or partially recovered from unsorted mixed municipal waste, or
2) storage of waste generated in the mechanical and biological processing of mixed municipal waste and storage of sorting residues from municipal waste[22].

Regulations regarding the acknowledgment of regional and supra-regional facilities were required to prepare provincial plans for waste management in 2016. Thus, such plans (which are still applicable, despite cancellation of the regional character) provide for the following types of regional facilities:

- RIPOK facilities for mechanical and biological processing of waste,
- so-called green RIPOK facilities – to process green waste and bio-waste,
- municipal waste landfill sites with the status of a RIPOK facility,
- plants for thermal conversion of municipal waste (Polish abbreviation: ITPOK), which meet the requirements imposed on regional facilities and do not have the status of a supra-regional facility.

In light of the provisions of the act on maintaining cleanliness and order in communes, communes are obligated to collect municipal waste as part of the waste management system. Moreover, every commune is to establish, independently or in conjunction with other communes, at least one stationary point of selective collection of municipal waste (Polish abbreviation: PSZOK), which should allow collection of at least such types of municipal waste like: medicines and chemicals past their expiry date, used batteries and rechargeable batteries, used electric and electronic equipment, furniture and other large-size waste, used tires, green waste and construction and demolition waste constituting

[21] Act dated 19 July 2019 on amendment to the act on maintaining cleanliness and order in communes and in certain other acts, Polish Journal of Laws 2019 item 1579.

[22] Act on waste (Polish Journal of Laws 2013 item 21 with further amendments) as amended in 2019 (Polish Journal of Laws 2019, item 1579), Art. 35, section 6.

municipal waste. Communes can also establish and maintain repairs and reuse points for non-waste products or parts of products[23]. Rules of selective collection of waste have been regulated by the ordinance on detailed method of selective collection of certain waste fractions[24] which was adopted at the end of 2016. The ordinance orders performance of selective collection in labeled containers (eventually, in bags at the place of generation) of the following fractions:

- paper,
- glass,
- metals,
- plastic,
- waste subject to biodegradation, with a particular consideration of bio-waste.

The regulation is not only of legal but also of organizational and technological nature since it forces the implementation of a handling system (collection, transport, management) for every selectively collected fraction. The implementation of those requirements is to favor the increase of efficiency in achieving environmental goals in municipal waste management, particularly within the scope of achieving a higher level of recycling and preparation to reuse specific fractions of waste. The regulation came into force on 1 July 2017. However, it allows conducting selective collection of waste according to the previous rules applicable in communes until the currently performed agreements for collection and management of waste expire, but it must be no longer than by 30 June 2021.

It should be highlighted it is necessary to collect fractions of biodegradable waste, since (so far) its selective collection has been uncommon and has involved only certain business entities, such as gastronomic companies or owners of properties with communal gardens (collection of mown turf or leaves). Biodegradable waste that must be collected in a brown container or bag includes, among others: fruit and vegetable waste (including peelings), tree and bush branches, mown turf, leaves, flowers, sawdust and bark, or food leftovers. It must be, however, highlighted that the act on waste allows natural persons

[23] Act on maintaining cleanliness…, op. cit., Art. 3 section 2 points 6 and 6a.

[24] Ordinance of the Minister of the Environment dated 29 December 2016 on detailed method of selective collection of certain waste fractions, Polish Journal of Laws 2017 item 19. This ordinance was modified in 2018 – consolidated text in the Notice of the Minister of the Environment dated 7 October 2019 on publication of the consolidated text of the ordinance of the Minister of the Environment on detailed method of selective collection of certain waste fractions, Polish Journal of Laws 2019 item 2028.

to conduct composting for their own use[25]. That is why in a situation in which a real property owner proves to have an operational composter, they do not have to collect waste subject to biodegradation into the specified container.

Mechanical and biological processing

The technology of mechanical and biological processing of waste (in short: MBP) in its current state was developed in Germany in the second half of the 1990s due to the introduction of regulations that forced preliminary processing of municipal waste prior to its storage. Initially, the technology was to ensure higher density of processed waste for integrating the landfill into the landfill body. Nowadays, the term of MBP has been understood as a set of processing techniques and methods that cover the following groups of processes[26]:

- mechanical processes – grinding, sieving, sorting, classification, separation, and other processes set in various configurations in order to separate the stream of waste into fractions that can be fully or partially used as materials and/or into fractions subject to biodegradation, in a way compatible with biological processing,
- biological processes – aerobic and anaerobic processing of waste subject to biodegradation into products similar to compost, and in case of fermentation – also into biogas.

MBP systems include both very simple facilities based on individual machines, preparing waste for storage, as well as expensive, developed facilities that prepare waste not only for storage, but also for incineration and use as materials.

Among MBP technologies, one should, above all, distinguish two solutions:

- mechanical and biological processing of waste as the technology for its preparation for storage,
- mechanical and biological processing of waste preceding thermal processing, i.e. the so-called biological dehumidification.

In the first case, the flow of waste is subjected to mechanical extraction of fractions rich in components with high heating value as well as fractions of ferrous and non-ferrous metals. The remaining flow of waste, rich in organic substance, is subjected to biological stabilization and then stored. The basic

[25] Act on waste, op. cit., Art. 30 point 2.

[26] A. Jędrczak, *Biologiczne przetwarzanie odpadów*, Wyd. Naukowe PWN, Warsaw 2008, p. 260.

process to initially separate the waste stream is sieving, usually through a drum screen, with mesh size of 80 to 150 mm. On some occassions, the sieving process is preceded by grinding. Both streams that leave the sieving process – meaning the oversize and the undersize - involve separation of ferromagnetic metals. The oversize fraction, as material of significant heating value, is usually processed (through, i.a. grinding and dehumidification) into the so-called alternative fuel (in short: RDF, Refuse Derived Fuel). RDF is intended for recovery of energy through incineration and co-incineration of waste. Nowadays in Poland, cement plants have been the main recipients of RDF. In the future, this group will also include incineration plants designed to use this particular type of fuel. It is assumed that the mass of the stream of the oversize fraction constitutes about 35% of the feedstock, while an average of 45% of the input mass stream is sent to the biological part[27].

Due to the process of stabilization of the undersize, the technology aimed at preparation of waste for storage differentiates two variants of the process: with aerobic or anaerobic stabilization of the bio-fraction.

The regulation on mechanical and biological processing of mixed municipal waste[28] specifies the conditions that must be fulfilled both in the aerobic and the anaerobic variant of the process. In the case of the aerobic process (the most frequently used technology), waste must be processed for a period of 8 to 12 weeks in total. For at least the first two weeks, the process takes place in a closed reactor or a hall, with active aeration, preventing the untreated process air from being released into the atmosphere, until the AT4 value (understood as breathing activity – a parameter that expresses the oxygen needed by the sample of waste for 4 days) drops below 20 mg O_2/g of the dry mass. The next step is to conduct the stabilization of processed waste in piles in open air; the piles are aerated through turning at least once a week.

The process of biological processing of mixed municipal waste should be conducted in a way in which the obtained stabilized compost meets the following requirements:

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[27] G. Wielgosiński, O. Namiecińska, P. Saladra, *Termiczne przekształcanie odpadów komunalnych w Polsce w świetle nowych planów gospodarki odpadami*, "Nowa Energia", 2017 issue 2, pp. 25-30.

[28] Ordinance of the Minister of the Environment dated 11 September 2012 on mechanical and biological processing of mixed municipal waste, Polish Journal of Laws 2012 item 1052. Officially, it is outdated; the legal grounds were repealed. There is, however, no applicable regulation that would regulate the MBP process; this text describes the currently applied provisions.

1. Loss on ignition of the stabilized compost in lower than 35% of the dry mass,
2. The content of organic carbon is lower than 20% of the dry mass,
3. The AT4 value is lower than 10 mg O_2/g of the dry mass[29].

Stabilized compost (waste with code 19 05 99) that meets the above requirements can be utilized through storage at non-hazardous or non-neutral waste landfill sites or, after being sieved through a screen with a mesh size of up to 20 mm, it can be used as waste with code 19 05 03 (off-specification compost) for recovery processes (e.g. biological rehabilitation of a closed waste deport or its part).

Storage

Storage stands for treatment of waste that has not been used for economic purposes or was not utilized in another manner. It involves long-term disposal of waste at places intended for that purpose, in a way that is safe for humans and the environment.

A landfill site is a building structure located and arranged according to regulations for organized disposal of waste with certain known properties. There are three types of waste landfill sites: hazardous waste landfill, neutral waste landfill, and landfill of non-hazardous and non-neutral waste – the last category includes municipal waste.

Landfill sites belong to a group of engineering structures that involve the highest requirements and difficulties due to[30]:

- covering an area of several thousand to several hundred thousand square meters,
- a volume of several thousand to a dozen million cubic meters of waste,
- thickness of stored waste of up to several dozen meters,
- an exploitation period of up to several dozen years,
- the necessity of ensuring stability of the soil and of stored waste,
- requirements regarding the maximum tightness and the minimum impact on the surroundings.

[29] Ordinance of the Council of Ministers dated 22 December 2017 on unit rates for fees for the use of the environment, Polish Journal of Laws 2017 item 2490.

[30] Cz. Rosik-Dulewska, *Podstawy gospodarki odpadami*, Wyd. Naukowe PWN, Warsaw 2012, pp. 73-74.

The guidelines regarding construction, exploitation or closure of landfill sites, as well as the storage process itself, have been provided for in legal regulations, such as:

- the Ordinance on waste landfill sites[31],
- the Ordinance on types of waste that can be stored at waste landfill sites in a non-selective manner[32],
- the Ordinance on admitting waste to be stored at waste landfill sites[33].

The technical requirements imposed on modern landfill site, which are regulated, in detail, in the first of the a/m ordinances, include:

- systems to secure ground, surface and underground water against the impact of waste – natural or artificial insulating geological barriers are used to seal the ground and the side walls of the landfill site;
- systems to drain and treat sewage that ensure the reliable functioning of the landfill site during its exploitation and for at least thirty years following its closure;
- systems to drain and manage biogas generated in the mass of stored waste – biogas must be refined and used for power generation purposes;
- technical equipment to form and concentrate waste, ensuring geotechnical stability of stored waste;
- systems to control the impact of the landfill site on the environment; in the following stages: pre-exploitation, exploitation, and post-exploitation stage (30 years following the closure of the landfill site), the controls cover, among others: the quality and amount of ground and surface water and leachates, the quality and amount of biogas, the settling of stored waste;
- systems for rehabilitation processes.

In the case of waste from group 20 (municipal waste including selectively accumulated fractions) and designated with code 19 12 12 (such code is used to label the undersize fraction of municipal waste prior to being subjected to biological processes), it is prohibited to store waste that feature a content of total organic carbon (TOC) exceeding 5% of the dry mass, loss on ignition (LOI)

[31] Ordinance of the Minister of the Environment dated 30 April 2013 on waste landfill sites, Polish Journal of Laws 2013 item 523.

[32] Ordinance of the Minister of Economy dated 16 January 2015 on types of waste that can be stored at waste landfill sites in a non-selective manner, Polish Journal of Laws 2015 item 110.

[33] Ordinance of the Minister of Economy dated 16 July 2015 on admitting waste to be stored at waste landfill sites, Polish Journal of Laws 2015 item 1277.

exceeding 8% of the dry mass, or heat of combustion over 6 MJ/kg of the dry mass[34]. In practice, it means that it is necessary to subject the unprocessed mixed municipal waste to management processes other than disposal through storage.

Waste incineration[35]

To put it simply, incineration is an oxidation process that involves generation of high amount of heat and radiant energy (glowing). It is commonly said that incineration stands for energetic combination of organic matter of waste with oxygen[36].

Thermal processes of waste conversion allow[37]:

- recovery of energy, which is of great importance due to the increased prices of energy from unconventional sources (natural gas, oil),
- decrease in volume of waste – the volume of permanent residues of thermal processes is several times smaller than the volume of waste; moreover, they can be subjected to further processing in order to extract the substances they contain.

Over the last several decades, incineration has become an essential method of disposal of municipal as well as industrial waste, especially hazardous waste. It is necessary to thoroughly analyze the waste that will be subjected to incineration in order to choose the proper technology of thermal processing. In the case of municipal waste, significant factors include high involvement of combustible part and the possibility of useful management of generated secondary waste. Municipal waste with proper properties (heating value, availability, air as the oxidant, etc.) is considered as fuel and serves the role of an energy carrier[38]. The main purpose of incineration of waste is to convert waste into a state that poses no threat to the environment and to people, while the advantages achieved with this method (potentially useful ashes, electricity and thermal

[34] Ordinance of the Minister of Economy dated 16 July 2015 on admitting waste…, op. cit. § 3.3.

[35] Further reading: J. Famielec, S. Famielec, *Ekonomiczne i techniczne uwarunkowania procesów spalania odpadów komunalnych*, "Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu", 2016 issue 454.

[36] *Słownik chemiczny*, ed. J. Chodkowski, Wyd. Wiedza Powszechna, Warsaw 2018.

[37] L.N. Nemerow, *Industrial Waste Treatment*, Elsevier Science and Technology, Boston 2007.

[38] C.T. Szyjko, *Odzysk energii z odpadów komunalnych. Wyzwania dla Polski*, "Energia. Gigawat", 2013 issue 1.

energy) constitute the added value of the process (consequently, it also meets the currently applicable definition of disposal of waste).

Heating value is one of the most important properties of fuel. It stands for the amount of energy generated as heat during combustion of a mass unit or volume unit of fuel[39]. Heating value is usually expressed in MJ/kg or MJ/m^3 (sometimes also in kJ/kg or kJ/m^3).

The autothermal property of incineration means that waste can be combusted on a stable basis without the need of feeding additional fuel. The assumed criteria of autothermal property are the minimum combustion temperature or the minimum heating value of waste[40]. In the case of municipal waste, it can be safely estimated that the autothermal property of incineration requires a combustion temperature of 850-900°C. The minimum criterion of heating value results from experience in the scope of incineration of waste. It is expected that the process of waste incineration features the autothermal property if the heating value of waste is at least 6 MJ/kg. However, it must be highlighted that the autothermal property of waste incineration processes is affected, apart from the heating value, by parameters such as the content of combustible parts, mineral parts, and moisture in waste. Normally, the area of autothermal incineration is a range limited by parameters: percentage of combustible parts of minimum 25%, percentage of non-combustible parts of maximum 60%, percentage of moisture of maximum 50%. Bearing in mind the morphological content of municipal waste in Poland, it can be assumed that they fall within the range of autothermal incineration. The heating value of municipal waste in Poland falls within 7-9 MJ/kg[41], which means that the condition of the autothermal property is also met in this aspect.

The autothermal property of incineration is desirable, because it allows thermal conversion of waste without additional fuel and it facilitates recovery of a part of energy in the combustible components of waste. However, one should not treat the conditions of autothermal incineration of waste as conditions needed for its safe conversion. The energetic effect of waste incineration is subordinated

[39] J. Szargut, *Termodynamika techniczna*, Wyd. Politechniki Śląskiej, Gliwice 2013.

[40] *Spalanie i paliwa*, ed. W. Kordylewski, Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2005.

[41] G. Wielgosiński, O. Namiecińska, *Spalarnie odpadów komunalnych - perspektywa roku 2020*, "Nowa Energia", 2016 issue 2, pp. 11-20.

to purposes such as decreasing the volume of waste, detoxification of waste, and preservation of environmental and safety standards. Thus, regardless the autothermal conditions of incineration, it is necessary to ensure a combustion temperature that guarantees the required efficiency of thermal conversion of waste.

There are many different solutions concerning technological systems for thermal conversion of waste. When it comes to construction, the following types of furnaces are distinguished[42]: chamber, grate, fluidal, rotary, and multiple hearth furnace.

Grate furnaces are widely used in municipal waste incineration plants. The waste is incinerated on a grate the construction of which allows combining waste with air and slow transport of the incinerated feedstock. Generally, three zones can be distinguished in a grate furnace – the first zone is used to dry the feedstock, the second is used for degasification and incineration, while the third – for afterburning. The excess of air should wall within 100-200%. The grate furnace should be thermally insulated with proper fire-retardant material. Typical temperatures of incineration of municipal waste on a grate reach 1000-1200°C. The advantage of a grate furnace is, above all, the ability to incinerate waste of various size and even form, without the need for preliminary grinding. Moreover, such furnaces are very reliable and feature a wide range of heat load variations. The disadvantages, on the other hand, include complicated power feed, necessity of thorough maintenance, and significant investment and exploitation costs.

Apart from exhaust released into the atmosphere, incineration of waste emits pollutants typical of power boilers (fly ash, SO_2, NO_x, CO_2, CO) and, what is more, many organic compounds, including PAHs, dioxins and furans, as well as hydrogen chloride, hydrogen fluoride, and heavy metals. The group of organic compounds, which includes volatile compounds (VOCs), is particularly large[43].

In order to control emissions of pollution during incineration of waste at waste incineration and co-incineration plants, it is necessary to conduct continuous or periodic measurement of concentration of pollutants in the exhaust

[42] M.J. Rogoff, F. Screve, *Waste-to-Energy. Technologies and project implementation*, Elsevier Science and Technology, Boston 2011 and G. Wielgosiński, *Przegląd technologii termicznego przekształcania odpadów*, "Nowa Energia", 2011 issue 1, pp. 55-67.

[43] J. Warych, *Oczyszczanie przemysłowych gazów odlotowych*, Wyd. Naukowo-Techniczne, Warsaw 1994 and G. Wielgosiński, *Przegląd technologii termicznego przekształcania odpadów*, op. cit., pp. 55-67.

emitted into the atmosphere. Continuous measurement should include: total dust, NO_x, HCl, CO, LZO, HF, SO_2 and O_2 (to assess the correctness of the process and to calculate other values). Periodic measurement includes: Pb, Cr, Cu, Mn, Ni, As, Cd, Hg, Tl, Sb, V, CO as well as dioxins and furans[44].

Due to the environmental requirements regarding treatment of exhaust, waste incineration plants had to be facilitated with proper nodes that would remove pollution from the exhaust. Then, a standard technological line includes dedusting of exhaust, its desulfurization (sulfur oxide bonds), reduction of nitrogen oxides, washing machines that remove acidic pollution from exhaust, filters (usually made of activated carbon) that absorb heavy metals, VOCs, dioxins and furans. That is why in modern waste incineration plants the furnace and the eventual boiler constitute only one technological node of a whole line[45].

The ash and slag created during incineration of waste constitute a significant problem for the operators of waste incineration facilities since they usually contain an array of substances that qualify them as hazardous waste. Those substances include, among others, heavy metals as well as dioxins and furans that set on ash particles. Some of those pollutants can be easily purged, which may pose a threat of contaminating ground water. Thus, storage of ash generated from incineration of waste, in case of no capabilities for their safe use, requires storing at hazardous waste landfill sites. Due to the same reasons, co-incineration of waste with carbon poses the same problems because it hinders the economic use of ash.

1.3. Organization of the municipal waste management system as the role of the commune

The management of and governance over waste have been entrusted to communes[46]. The new philosophy behind this strategy is to reuse as much capable waste as possible through sorting, recycling, and recovery. Other waste

[44] Notice of the Minister of the Environment dated 15 October 2019 on publication of the consolidated text of the Ordinance of the Minister of the Environment on requirements within the scope of measurement of emissions and amount of used water, Polish Journal of Laws 2019 item 2285.

[45] J. Warych, *Oczyszczanie przemysłowych gazów odlotowych*, Wyd. Naukowo-Techniczne, Warsaw 1994 and G. Wielgosiński, *Przegląd technologii termicznego przekształcania odpadów*, op. cit., pp. 55-67.

[46] Further reading: J. Famielec, S. Famielec, *Restrukturyzacja sektora gospodarki odpadami komunalnymi*, op. cit.

that can be subjected to thermal utilization should be incinerated and only the remaining waste, incompatible with other forms of utilization, should be stored.

Communes are the basic – statutory – body to perform tasks regarding management of municipal waste. Therefore, the municipal council develops its own terms and conditions with regard to maintaining cleanliness and order within the commune (after consulting the district sanitary inspectorate). The terms and conditions state, among others, detailed rules for maintaining cleanliness and order within the commune as to: collection and acceptance of municipal waste within a set scope, including waste generated at households, hazardous waste, large-size waste, and waste from renovations.

The commune may perform the duties within the scope of management of municipal waste in two ways:

- the commune directly manages the system and conducts tenders to choose entities that render waste export services,
- the tasks related to system management are entrusted to another legal person, through a tender or without a tender – in the so-called in-house mode.

The in-house mode is a special procedure of entrusting the management or/and handling of the municipal waste management system to a municipal company that must meet the following conditions:

- it must be owned by the commune throughout the whole period of implementation of public utility tasks,
- it must be controlled by the commune in the same extent as in the case of its organizational units, by controlling its statutory bodies,
- activities of the company must be conducted in favor of the commune that it is owned by.

The model of in-house procurement in municipal waste management has been applied in large Polish cities since at least 2010. In cities such as: Cracow, Białystok, Bydgoszcz, Szczecin, this mode has been used to entrust own tasks of communes to municipal companies within the scope of construction of facilities for thermal processing of municipal waste, co-financed with subsidies from the EU[47].

[47] S. Podgórski, *Dopuszczalność prawna i zalety powierzenia typu in house*, "Przegląd Komunalny", 2016 issue 4, p. 31.

The beginnings of the debate regarding in-house procurement within the scope of collection and transport of municipal waste date back to 2011[48], the year of adoption of the amendment to the act on maintaining cleanliness and order in communes (1996)[49] which initiated the establishment of municipal waste management systems in communes. On one hand, the changes were revolutionary, yet at the same time it was decided that the organizational independence of communes should be limited by obligating them to conduct competition proceedings in case of realization of new waste-related investments. It was also ordered to organize tenders for collection and management of municipal waste. Thus, communes could not, in general, entrust the tasks within the scope of municipal waste management to their own organizational units - such as budgetary plants, municipal companies – in the in-house mode[50]. Communes would express their disaffection and bring up the constitutional rule of organizational independency; they would file complaints to the Constitutional Tribunal. Communes were supported by the Waste Management Employers Association, the National Chamber of Waste Management, and other organizations. At the same time, there were pending works over changes in the public procurement law, including the EU. In February 2014, the new Directive of the European Parliament on public procurement was adopted[51]. The Directive indicated, among others, the necessity of providing more precise information as to situations in which contracts concluded in the public sector would not be subject to the obligation of applying public procurement regulations. It was highlighted that the application of regulations regarding public procurement should not disrupt the freedom of public institutions as to the tasks they were entrusted with in terms of public services, execution of own resources, or cooperation with other public institutions. Presumptions were established that, when all met, allow application of in-house procurement. Such procurement was included in the regime of public procurement and member states were obligated to implement those regulations within two years, i.e. by 18 April 2016.

[48] M. Kiełbus, *Gra o in house – koniec kolejnego sezonu*, "Przegląd Komunalny", 2016 issue 7, p. 37.

[49] Act dated 11 July 2011 on amendment to the act on maintaining cleanliness and order in communes and certain acts, Polish Journal of Laws 2011 no. 152 item 897 with further amendments.

[50] M. Kiełbus, Gra o in house – koniec kolejnego *sezonu*, "Przegląd Komunalny", 2016 issue 7, p. 37.

[51] Directive 2014/24/EU of the European Parliament and the Council on public procurement, repealing Directive 2004/18/EC.

The implementation of provisions of the directive in Poland was made by way of amendment to the public procurement law dated 22 June 2016 which fully repealed the previously applicable obligation of communes as to ensuring construction, maintenance or exploitation of regional municipal waste processing facilities with the use of competitive modes[52]. The regulation saying that companies in cooperation with the commune can collect municipal waste from property owners upon order of the commune, in case of an appointment through tender, was also repealed. In the new regulations, it was decided that when the municipal council adopts a resolution on collection of municipal waste from owners of properties that are not inhabited by inhabitants, the head of the commune, the mayor or the president of the city is obligated to call for tenders for collection of waste from owners of those properties or for collection and management of such waste. Thus, the possibility of entrusting such tasks in the in-house mode was excluded[53]. Communes, on the other hand, are obligated to organize collection of municipal waste from owners of properties that are inhabited by inhabitants, by was of awarding public procurement for collection and management of municipal waste[54]. The regulation also covered the rule regarding collection of waste from mixed (inhabited and uninhabited) real properties by one entity, whereby it must be considered (by way of a resolution of the municipal council) whether the entity will be selected in the in-house mode or in a tender. The choice must be subordinated to the constitutionally guaranteed rule of the organizational independence of local self-government units, including communes. This independence is reflected in the ability to choose the organizational and legal form in which they implement their tasks, with the lowest possible interference of the state in this matter.

An important condition of a municipal company entitled to being awarded an in-house procurement is that over 80% of activities of the controlled legal person – according to Directive 2014/24 of the European Parliament and the Council – and over 90% (according to the amended public procurement law

[52] Act dated 13 July 2016 on amendment to the Public Procurement Law and certan other laws, Polish Journal of Laws 2016 item 1020. Amended: Act dated 29 January 2004 – Public Procurement Law, Polish Journal of Laws 2015 item 2164 and 2016 items 831 and 996.

[53] K.M. Ziemski, M. Karciarz, M. Kiełbus, *In house a odbiór odpadów z nieruchomości mieszanych,* "Przegląd Komunalny", 2016 issue 10, p. 34.

[54] Act dated 13 July 2016 on amendment to the Public Procurement Law…, op. cit., Art. 7.

in Poland[55]) must be conducted as a part of tasks entrusted to the company by the controlling ordering party or by other legal persons controlled by the ordering institution. In this case, control means 100% of interest in the share capital of the controlling entity, while the percentage of activities of the contracted can be measured by the total turnover or possible costs in the last three years preceding the procurement[56].

The commune, if interested, may utilize, under statutory rules, the possibility of an in-house procurement, but it is not mandatory. The exceptions from this rule were limited to two cases requiring conduction of a tender according to the public procurement law:

- lack of own municipal company that would meet specific conditions and render services within the scope of collection of municipal waste or lack of willingness to apply the possibility of implementing such a task through an in-house procurement,
- uninhabited real property, which is not covered by the entitlement to in-house procurement with regard to collection and management of municipal waste generated by such real property.

In-house procurement is to help in eliminating unethical business owners who dispose of the collected municipal waste outside the chains of their management and in ensuring effective control. In this case, it particularly means the guarantee of a waste management hierarchy, care for the natural environment and local communities, optimization of municipal waste management processes, and limitation of unnecessary costs[57]. Some assessments exclude the threat of monopolization of the market and loss of effects of market competition. Some economists claim that the system of market tenders does not provide permanent effects of competition. Market mechanisms stop, the market becomes segmented, it is possible to establish a monopoly and, consequently, it is possible to establish oligopolies without control of service quality and their prices. The experience of Sweden, Denmark, and Germany proves that replacing the market mechanisms with the control of communes in municipal waste management was of key impor-

[55] Such exacerbation imposed by the directive and even stricter exacerbation in Polish delegations is to limit participation in competition on the open market for entities that are awarded procurements without a need to call a public tender.

[56] A. Gumniak, T. Mądry, *Kryteria stosowania zamówień in house w świetle nowych dyrektyw*, "Przegląd Komunalny", 2016 issue 5, p. 84.

[57] T. Uciński, *Skuteczniej z in house*, "Przegląd Komunalny", 2016 issue 5, p. 104.

tance for protection of the environment and proper management of municipal waste. It is assessed, that there is still place for private entities on those markets, since many communes in Poland do not have municipal companies. Waste processing facilities, e.g. incineration plants, due to their capital-intensive character, are sometimes private entities that receive municipal waste from communal companies, often after it was subjected to biological and mechanical processing.

In-house procurement is also used in other sectors of municipal management: public transport, collective supply of water and collection of sewage, construction and management of sports facilities[58].

Entrusting all public utility tasks of a city to one entity has, at least, three groups of limitations:

- the production capacity and factors of municipal companies and the technical and economic possibility of the expansion or modernization,
- the social and political factors of elimination of private entities that invested in manufacturing capacities, have been rendering public utility services within the scope of municipal waste (through tenders), often employ local workers, pay local taxes to the commune, compete for the local service market,
- uninhabited real property in the case of which collection, transport and management of waste must not be entrusted in the in-house mode but in form of a tender.

It is claimed that adopting the rule of procurement form of entrusting handling of uninhabited real properties is a peculiar safety fuse that prevents municipal companies from monopolization of the local market of municipal waste. However, even the fight for such procurement may involve fierce competition[59] between private and self-governmental entities or/and on markets in other communes in the region (except for the central city). The determination of private entities pushed out from the market of a particular commune to be awarded procurement in another commune would be substantial. Many

[58] S. Podgórski, *Dopuszczalność prawna i zalety powierzenia typu in house*, "Przegląd Komunalny", 2016 issue 4, p. 31.

[59] It is expected that there is a possibility of excessive abuse of the in-house mode. Poznań with its surroundings is an area of operation of large companies that enter the local market in an aggressive way and a small self-governmental company of municipal services would not be able to compete with them. Thus, decisions are made to make communes leave the intra-communal association, so that in the next year it will be possible to entrust collection of waste to own companies rather than those selected by the association in a tender. See L. Bojarski, *In house, czyli będzie kolejna rewolucja?*, "Przegląd Komunalny", 2016 issue 8, p. 9.

entities must repay loans and loss of revenue may pose a threat to their timely payments, which may lead to loss and detrimental to timeliness of tax processing performed by those entities and banks as well. Further consequences include employee's losing their jobs and having financial difficulties. The rolling costs of consequences of excessively aggressive execution of the instrument of in-house procurement by communes and local authorities can often be very unfavorable for local governments and the national budget, although the instrument has been in existence only since 2017, city and municipal councils should rationalize such decisions. The criterion should not be limited to benefits of individual municipal entities; it should acknowledge the anticipation of changes in the structure of the whole market, stricter competition and acceleration of unfavorable consolidation in the sector of municipal waste services.

1.4. Rules and paradigms of municipal waste management

The behavioral nature of waste management[60]

The basic difficulty concerning the establishment, implementation and management of a system for municipal waste management is connected with the number of its participants and the social character of individually emitted waste. The consumer, the inhabitant, being the most frequent wrong-doer, is incapable of ensuring disposal of waste without causing damage to the surroundings. He or she is unable to individually pay for the access to more and more modern and expensive infrastructure. His or her behavior can only be consistent with the reasonableness dictated by their conscience. The conscience, on the other hand, motivates them to avoid financial burden and to limit the care for "own yard".

Such behavior is described in economics as:

- the herd effect (most people do whatever others do, in the same manner as others),
- the tragedy of mutual pasture (exploitation of common good, e.g. ditches, forests, public land, where municipal waste is eagerly thrown away, to

[60] Further reading: J. Famielec, *Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym*, op. cit.

the highest possible extent, regardless the knowledge and level of education of the emitters),

- the NIMBY syndrome[61] (*not in my back yard*, a common objection to certain investments in the nearest neighborhood, despite the fact that they are necessary).

Such behavior is impartial and does not even react to the law, prohibitions, or orders. It expresses behavioral individual and group properties that also include opportunism (e.g. tax evasion). Thus, solving the problem of the necessary responsibility of the emitter of municipal waste for its generation and management ("cleaning up") is beyond the regulation of such behavior. Results of the emission of municipal waste become social, they involve the surroundings - the people and the environment. The area is the witness of numerous conflicts of interest and attitudes, also with regard to the testament for future generations.

The elaborated current solutions for this difficult problem in the EU and in Poland are based on new paradigms. Those include the following:

- waste does not only pose a threat to and pollute the environment; it is also a source of raw materials and resources as well as an area of taking responsibility for the nature,
- refraining from storage – more and more recycling, recovery and thermal processing,
- optimization of the organization of processing and removal of waste,
- integrated and balanced management of municipal waste.

It should be mentioned that the responsibility for implementation of goals of municipal waste management must not be imposed on communes only. It should also originate from a change in the social mindset of the inhabitants and the corporate liability for permanent and balanced development. In this scope, one may even find interesting initiatives in banks for which environmental activities are the criterion for financing of business undertakings[62].

[61] H. Folmer, L. Gabel, H. Opschor, *Ekonomia środowiska i zasobów naturalnych*, Wyd. Krupski i S-ka, Warsaw 1996, p. 471.

[62] The Co-operative Bank in Great Britain made social and environmental activities to be the key property of brand identity and differentiation. It supports business undertakings that deal with, among others, processing of waste and balanced management of such waste. Ch. Laszlo, *Firma zrównoważonego rozwoju*, Wyd. Studio Emka, Warsaw 2008, p. 119 and H. Folmer, L. Gabel, H. Opschor, *Ekonomia środowiska i zasobów naturalnych*, Wyd. Krupski i S-ka, Warsaw 1996, pp. 228-229.

Integrated and balanced management of municipal waste

The Strategy of Energy and Environmental Safety, adopted in 2014, is one of the national strategic documents that constitutes the strategic framework for program and implementation works regarding waste management as such, including municipal waste[63]. The main purpose of that strategy is to: "ensure high quality of the contemporary and future generations with the acknowledgment of environmental protection and to create conditions for balanced development of a modern power sector that would be capable of providing Poland with energy security and competitive and efficient economy". The strategy formulates three detailed goals:

1) balanced management of natural resources;
2) providing national economy with a safe and competitive power supply;
3) improvement of the condition of the environment.

The strategy constitutes the grounds for the national[64] and provincial plans for management of waste[65] by 2022. Waste management plans are developed at national and provincial level in order to achieve the goals assumed in the national policy of environmental protection, separate the tendency of growing amount of generated waste and their impact on the environment from the tendency of the economic growth of the country, implementation of a hierarchy of methods for handling of waste and the rule of sustainability and closeness (so-called processing of waste as close to the place of its generation as possible), as well as to establish and maintain a national integrated and sufficient network of waste management facilities that meet the requirements of environmental protection[66]. Such plans should be updated not less frequently than every 6 years. The currently applicable plan is the national waste management plan 2022 (in short: KPGO 2022) and provincial plans 2016-2022 adopted in 2016.

The waste management plan discusses and regulates, among others, the type, source, amount and quality of generated waste. The amount of collected

[63] Resolution no. 58 of the Council of Ministers dated 15 April 2014 on adoption of the Strategy of Power Safety and the Environment – prospects until 2020, Official Journal of the Republic of Poland 2014 item 469.

[64] Resolution no. 88 of the Council of Ministers dated 1 July 2016 on the national waste management plan for 2022, Official Journal of the Republic of Poland 2016 item 784.

[65] These plans also have their legal base in the act on waste…, op. cit.

[66] Act dated 14 December 2012 on waste, op. cit., Art. 34.

municipal waste is strictly correlated with the economic condition of individual regions in the country. In particular, the parameters include as follows:

- type of area (city/town, village),
- population density,
- type of development – single-family/multi-family,
- number of tourists,
- presence of public utility structures,
- presence, type, number and size of commercial facilities and small-scale industry/services.

Integrated and balanced management of municipal waste involves:

- strategic activities favoring production, consumption, environmental policy, social policy,
- limitation of generation and harmfulness of waste as such,
- provision of safe, well-controlled and well-organized handling of waste as such - horizontal framework for management of waste,
- a coordinated set of legal regulations regarding refining and disposal of waste (a coordinated package of directives and acts),
- application of the best technology in a particular area, in a particular region,
- application of the "polluter pays" rule[67] as the basic form of the emitter's responsibility for the impact of waste they generate.

The balancing of municipal waste management takes place at several levels: legal, economic, financial, organizational, technological, social, and political level. The last aspect is of particular importance.

According to the Constitution of the Republic of Poland, public authorities perform a policy that ensures environmental safety of the contemporary generation and future generations, while the obligation to protect the environment is attributable to public authorities. Public authorities support civil activities aimed at protection and improvement of the condition of the environment. Maintenance of cleanliness and order in communes, as it has been already highlighted, is one of the obligatory tasks of communes themselves. Communes ensure cleanliness and order within their territory and create conditions necessary to preserve them, in particular: they create conditions for performance

[67] Also called the "society pays" rule, see H. Rogall, *Ekonomia zrównoważonego rozwoju. Teoria i praktyka*, Wyd. Zysk i S-ka, Poznań 2010, p. 223.

of works connected with maintaining cleanliness and order within the commune and provide performance of such works through establishment of relevant organizational units. The ensure construction, maintenance and exploitation of own or co-owned (with other communes) regional municipal waste processing facilities – provided that the obligation to construct such facilities is provided for in the provincial plan for waste management, sewage collection stations, when connection of all real properties to the sewage network is impossible or generates excessive costs, and facilities and machinery to collect, transport and utilize animal carcasses or their parts. They cover all the real property owners within the territory of the commune with a municipal waste management system.

The rule "the polluter pays" – prices for management of municipal waste[68]

The price for services for producers of waste (in the case of municipal waste: the fee for municipal waste management) is the basic instrument used to enforce liability connected with pollution and the source of establishing funds for creating and exploiting an integrated municipal waste management system. According to the OECD classification, price instruments in waste management can be grouped in the following way[69]:

- the fee – the "price" paid for pollution. The polluters must pay for the alleged right to environmental services that consequently become, at least partially, one of the components of the cost and benefits. Fees can entail incentive and redistribution results;
- subsidy – a term used to describe financial aid that, in the case of environmental polluters, be an incentive to change their course of action or that is granted to economic entities that face problems concerning compliance with the standards. There exist the following forms of financial aid: subsidies, subsidized loans, tax relief. They are granted in order to stimulate pro-environmental activities undertaken by economic entities;
- deposit systems – in the case of which a surcharge is imposed on the price of environmentally hazardous products;

[68] Further reading: J. Famielec, *Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym*, op. cit.; *Pomoc państwa i zamówienia in house w procesach i zakładach przekształcania odpadów komunalnych*, op. cit.

[69] A. Graczyk, *Instrumenty rynkowe polityki ekologicznej. Teoria i praktyka*, Wyd. Uniwersytetu Ekonomicznego we Wrocławiu, Wrocław 2013, pp. 94-96.

- establishment of markets – on which entities would be able to purchase "permits" for the ongoing and future emission of pollutants or to sell their "emission permit" or waste (secondary raw material). The following can be distinguished here: trade in emissions, price interventions in the functioning of the market, liability insurance;
- financial incentives for execution of law – which are on the periphery of division of instruments of environmental protection into economic and legal instruments.

There are two main types of incentives:

- penalties for breaching the conditions of use of the environment, when the polluter does not meet specific regulations,
- ecological liens, i.e. payments in favor of authorities in a situation when a breach of regulations is expected; compliance with the regulations results in a refund.

The rule "the polluter pays" means that the party which did damage to the environment (producer of municipal waste – consumer) should pay the costs to prevent or compensate such damage. This rule leads to a situation in which the social collective responsibility (of the taxpayers) can be – at least partially – transferred to the polluter. As a result:

- during the identification of the polluter, it is necessary to avoid public financing of damage to the environment,
- the polluter should be obligated to make investments necessary to achieve certain quality standards and norms in collection, transport, and management of waste,
- producers are obligated to care for the recycling and safe disposal of waste as well as to incur the costs of those processes.

Among fees collected for municipal waste management that constitute the income of the commune, the commune funds the functioning of the municipal waste management system, which includes costs of:

- collection, transport, accumulation, recovery and disposal of municipal waste (including, as an objective, thermal processing of waste),
- establishment and maintenance of points of selective collection of municipal waste,
- administrative handling of the system.

The commune may use the fees for municipal waste management to pay the costs of facilitating real properties with containers and bags for collection of waste.

The municipal council is to adopt, by way of a resolution, the maximum rates for fees incurred by owners of real property for services of collection of municipal waste, by applying varied rates depending on population density in a specific area of the commune or the distance from the site used for disposal of municipal waste. When determining the rates of fees for real property owners, the municipal council applies lower rates if municipal waste is accumulated and collected selectively. The head of commune, the mayor, the president of the city issues ex officio a decision (for 1 year), in which they determine:

- the obligation to pay fees for collection of municipal waste (including sorted waste) or emptying of septic tanks,
- the amount of fees calculated by using maximum rates determined by the municipal council (including the rate for sorted waste).

The fees for municipal waste management are adopted based on estimated costs of municipal waste management in the commune, applying a selected conversion rate: per number of inhabitants of a particular real property, amount of water used by a particular real property, or by floor space of residential premises, which has evoked – so far – many economic, political, and social controversies[70].

Apart from the fee for municipal waste management, there is also the requirement of paying an environmental fee for the use of the environment in form of a fee for placement of waste at a waste landfill site[71]. It is a fee that has been determined ex officio for placement of waste at a landfill site by an operator or administrator of the landfill site. It is paid to the financial department of the marshal's office (that is why it is sometimes referred to as the marshal's fee). It is subjected to further distribution in the system of environmental and water management (new rates – Table 1 and Chart 1).

[70] Act dated 13 September 1996 on maintaining cleanliness and order…, op. cit.

[71] Notice of the Marshal of the Sejm of Republic of Poland dated 19 July 2019 on publication of the consolidated text of the Environmental Protection Law, Polish Journal of Laws 2019 item 1396.

Table 1. New rates of fees for placement of waste at a landfill site in Poland [PLN/Mg]

Type	Code	2018	2019	2020 and sub. years
Unsorted mixed municipal waste	20 03 01	140[b]	170	270
Other waste from mechanical processing of waste	19 12 12	140[c]	170	270
Other waste from aerobic processing of waste [a]	19 05 99	140 35[a]	170 42.5[a]	270 67.5[a]

[a] Excluding fees for 19 05 99 and 19 06 04 after biological processing of mixed municipal waste in the case of which the ratio of 0.25 applies.
[b] In 2016, 120.8 PLN/Mg.
[c] In 2016, PLN 74.3 PLN/Mg.

Source: own analysis based on: Ordinance of the Council of Ministers dated 22 December 2017 on unit rates for fees for the use of the environment, Polish Journal of Laws 2017 item 2490.

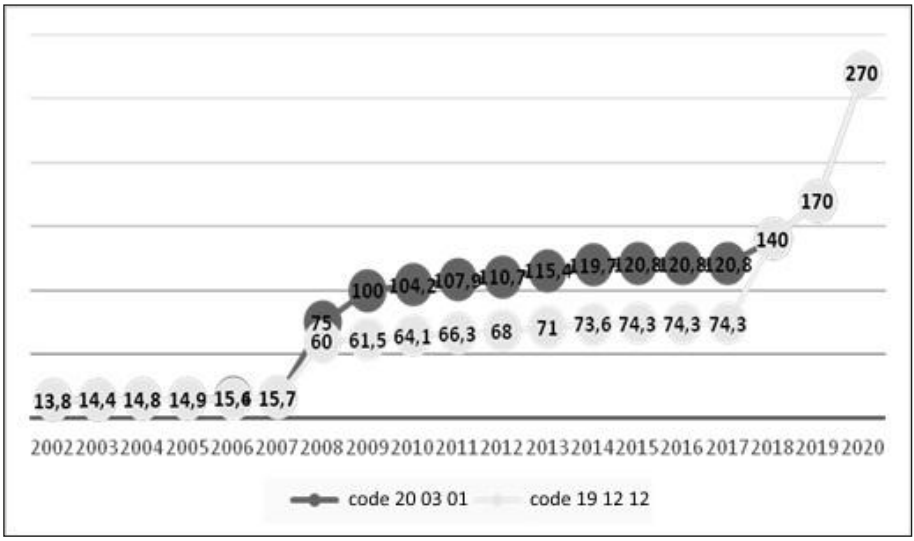

Chart 1. Evolution of the fee for placement of waste at a landfill site in Poland [PLN /Mg]

Source: own analysis based on the Ordinance of the Council of Ministers dated 22 December 2017 on unit rates for fees for the use of the environment, Polish Journal of Laws 2017 item 2490.

The comparison of flow of cash coming from the fee for waste management and for the use of the environment to the flow of waste streams in the communal waste management system has been presented in Diagram 3.

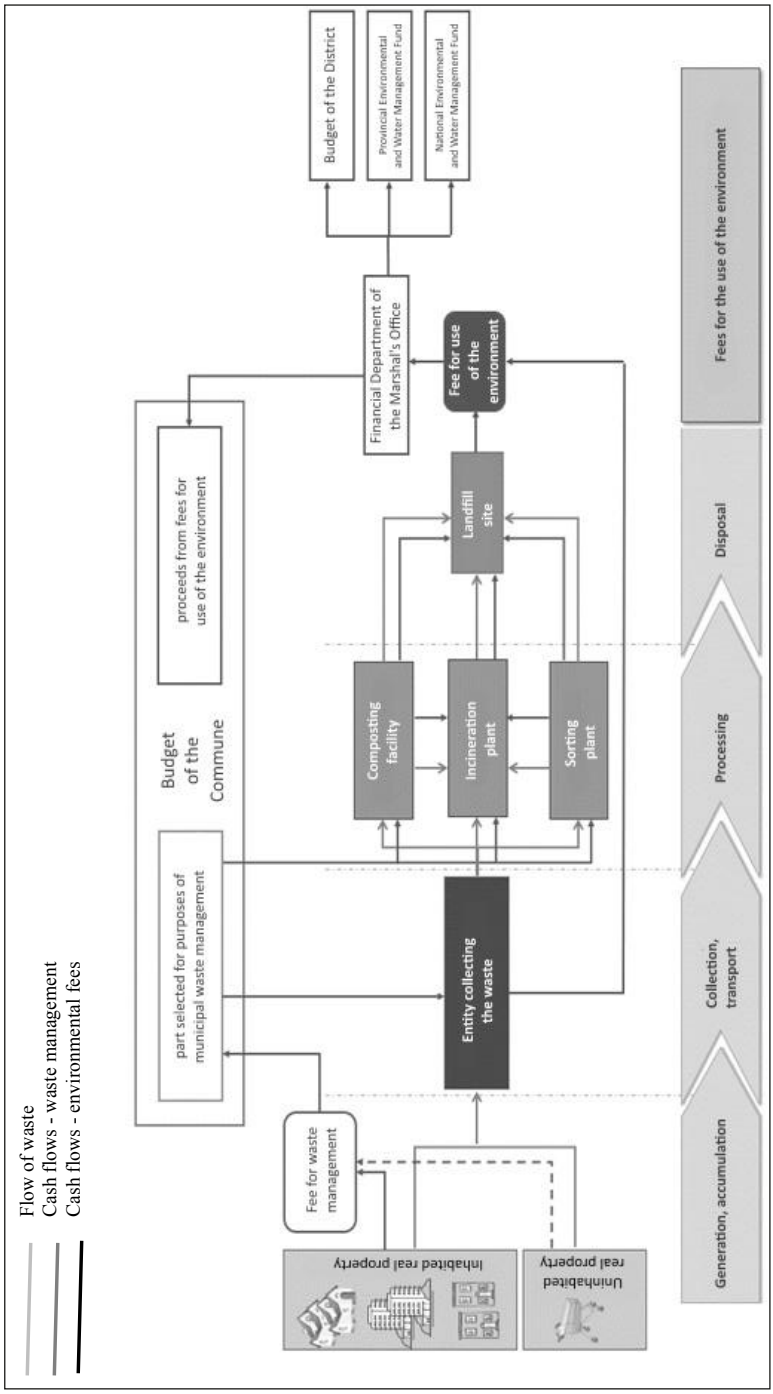

Diagram 3. The flow of waste and cash flow in the commune

Source: own analysis.

Standards and norms of municipal waste management

The character of tasks in municipal waste management is social, technological, environmental, economic. They must be achieved through fulfillment of standards regarding municipal waste management. The main obligations imposed on member states under numerous legal acts of the EU on municipal waste management (i.a. Directive 2008/98/EC) can be narrowed down to the following[72]:

- preparation of strategic documentation,
- issuance of administrative decisions,
- achieving specific levels of accumulation, recovery, including recycling, limitation of amount of biodegradable waste stored at waste landfill sites,
- meeting requirements regarding construction and exploitation of waste management facilities,
- meeting requirements within the scope of waste treatment,
- control of adherence to regulations,
- preparation of reports for the European Commission.

The specified obligations are performed at a national, provincial, district, and commune level. All the aspects connected with municipal waste management in a particular area by the national plan and a provincial plant for the specific area.

The National Waste Management Plan 2022 (KPGO 22) provides a list of detailed requirements imposed on Poland by the European Union, implemented in the domestic legislature in many legal documents, i.a. the act on maintaining cleanliness and order in communes. The requirements include, in particular:

- achieving the level of recycling and preparation to reuse of fractions of: paper, metals, plastic and glass from municipal waste at level of minimum 50% of its mass by 2020,
- achieving a level of recycling and preparation to redeployment of (non-hazardous) construction and demolition waste at level of minimum 70% of its mass by 2020,
- percentage of the mass of thermally processed municipal waste and waste originating from municipal waste processing compared to generated municipal waste must not exceed 30% by 2020,

[72] B.B. Kłopotek, *Zobowiązania unijne Polski w zakresie gospodarki odpadami komunalnymi*, Ministry of the Environment, Warsaw, www.spalarnia.krakow.pl/getFile.php?type=file&id=56&nocache, (DOA 27.11.2018).

- 60% of municipal waste must be subjected to recycling by 2025,
- 65% of municipal waste must be subjected to recycling by 2030,
- reduction of storage of municipal waste to maximum 10% by 2030,
- implementation of the system of selective collection of green waste and other bio-waste at source in all communes in the country – by the end of 2021.

One of the most important goals of waste management is, according to European regulations, the achievement of assumed levels of recycling and preparation to reuse. The levels to be achieved in the period of 2012-2020 as well as the methods to calculate them have been specified in the following ordinances: Ordinance of the Minister of the Environment dated 29 May 2012 on levels of recycling, preparation to reuse and recovery with other methods with regard to certain fractions of municipal waste[73] and Ordinance of the Minister of the Environment dated 14 December 2016 on levels of recycling, preparation to reuse and recovery with other methods with regard to certain fractions of municipal waste[74]. Levels in consecutive years have been presented in Table 2.

According to the guidelines in the ordinance[75], the level of recycling of and preparation to reuse paper, metals, plastic, and glass is calculated with the following formula:

$$P_{pmts} = \frac{Mr_{pmts}}{Mw_{pmts}} \bullet 100\% \quad (1)$$

where:

P_{pmts} – level ofa recycling of and preparation to reuse paper, metals, plastic, and glass, expresses in %,

Mr_{pmts} – total waste mass of paper, metal, plastic, and glass subjected to recycling and prepared to reuse, originating from the stream of municipal waste from households and other producers of municipal waste, expressed in Mg,

[73] Ordinance of the Minister of the Environment dated 29 May 2012 on levels of recycling, preparation to reuse and recycle with other methods with regard to certain fractions of municipal waste, Polish Journal of Laws 2012 item 645 – applicable until 30 December 2016.

[74] Ordinance of the Minister of the Environment dated 14 December 2016 on levels of recycling, preparation to reuse and recycle with methods other methods with regard to certain fractions of municipal waste, Polish Journal of Laws 2016 item 2167.

[75] Ordinance of the Minister of the Environment dated 14 December 2016 on levels of recycling…, op. cit.

Mw_{pmts} – total mass of generated waste of paper, metal, plastic, and glass originating from the stream of municipal waste from households and from other producers of municipal waste, expressed in Mg, in the case of communes calculated with the following formula:

$$Mw_{pmts} = Lm \bullet Mw_{GUS} \bullet Um_{pmts} \quad (2)$$

where:

Lm – number of commune inhabitants,

Mw_{GUS} – mass of municipal waste generated by one inhabitant in the area of the voivodeship (based on data of the Central Statistical Office),

Um_{pmts} – total percentage of waste of paper, metal, plastic, glass and composite waste in the morphological composition of municipal waste.

It must be highlighted that percentage of individual materials in the morphological composition (provided that the commune did not order own tests in this scope) must be based on the data in the current national waste management plan. The current KPGO 2022 has provided the morphological composition based on test results from 2008. Bearing in mind the extensive changes in the last years in the municipal waste management system and the social and economic structure in Poland, which affected the amount and composition of waste, it most certainly does not reflect the actual morphological composition of municipal waste generated today. It might lead to discrepancies between the calculated and the actual recycling and preparation to reuse.

Table 2. The required levels of recycling and reuse in Poland in years 2012-2020

Specification	Level of recycling and preparation to reuse [%]								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paper, metal, plastic, glass	10	12	14	16	18	20	30	40	50
	Level of recycling, prepare to reuse, and recovery with other methods [%]								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Non-hazardous const. and dem. waste	30	36	38	40	42	45	50	60	70

Source: Ordinance of the Minister of the Environment dated 14 December 2016 on levels of recycling…, op. cit.

As showed in the Report of the Supreme Chamber of Control titled "Implementation of commune tasks within the scope of municipal waste management"[76] published in June 2018, despite the fact that the monitored communes achieved the obligatory levels of recycling, in the case of more than a half of the communes, the reported data on levels of recycling was unreliable. Moreover, the report has indicated that the level of recycling reported by the communes in statistics deviates from the actual level. In some cases, the reported level of recycling might be lower than the actual, the reports of communes do not acknowledge secondary raw material buy-back centers, which also deploy some fractions of municipal waste for recycling. The example of Zielona Góra, which in 2015 imposed on buy-back centers the obligation to report the amount of collected secondary raw materials and disclosed a level of recycling equal 41.1% in that year, shows that the acknowledgment of streams of waste that gets through secondary raw material buy-back centers results in a significant increase in the achieved level of recycling.

In 2018, the Official Journal of the European Union was expanded by Directive of the European Parliament and the Council (EU) 2018/851 dated 30 May 2018 amending Directive 2008/98/EC on waste, which specifies the change tendencies of required levels of recycling and preparation to reuse in the perspective of the period until 2035. Article 11 of the amended Directive 2008/98/EC defines that member states shall establish selective collection at least for paper, metal, plastic, and glass while from 1 January 2025 – for textiles, and, moreover:

- by 2025, preparation to reuse and recycling of municipal waste will be increased, in terms of weight, to minimum 55%;
- by 2030, preparation to reuse and recycling of municipal waste will be increased, in terms of weight, to minimum 60%;
- by 2035, preparation to reuse and recycling of municipal waste will be increased, in terms of weight, to minimum 65%;

It must be highlighted that the European levels of recycling planned by 2025 and 2030 are lower by 5 percentage points than those assumed in KPGO 2022, which will most probably result in a correction of national requirements regarding the levels for the period until 2030.

[76] Full text of the report available online https://www.nik.gov.pl/kontrole/P/17/ (DOA 20.11.2018).

Moreover, communes are obligated to limit by 16 July 2020 the mass of biodegradable municipal waste deployed for storage to a level not higher than 35% of the total weight of biodegradable municipal waste deployed for storage compared to the mass of such waste generated in 1995.

Levels of limitation of the mass of biodegradable municipal waste deployed for storage that the commune is obligated to achieve in individual years have been currently specified in the Ordinance of the Minister of the Environment dated 15 December 2017 on levels of limitation regarding storage of municipal waste mass subject to biodegradation[77]. Those levels have been presented in Table 3.

Table 3. The determined levels of limitation regarding the mass of biodegradable municipal waste

Specification	2017	2018	2019	2020 – until 16 July
The permissible level of mass of biodegradable municipal waste deployed for storage compared to the mass of such waste generated in 1995 [%]	45	40	40	35

Source: Ordinance of the Minister of the Environment dated 15 December 2017 on levels of limitation regarding storage of municipal waste mass subject to biodegradation, Polish Journal of Laws 2017 item 2412.

Taking and executing responsibility with regard to municipal waste management is obstructed by the changeability and multitude of legal regulations. E. Łętowska asks: How can one keep track? What is the currently applicable regulation? She also decides that there are no grounds for the assessment of compliance of European law with Polish law. Stating such questions is useless, despite the fact that such compliance is the basis for the responsibility of the state, the commune. The questions should regard explanations referring to the contents of the European law that remains in a relationship to the analyzed case[78]. Polish law – after joining the EU – is multi-component as to its origins. That is only one of many reasons for the difficulties regarding its proper application. It also decreases the sense of responsibility of the parties that it refers to. This thought does not only take into consideration the municipal waste management and it obstructs achieving and assessing relevant standards and norms.

[77] Polish Journal of Laws 2017 item 2412.

[78] E. Łętowska, K. Pawłowski, *O prawie i o mitach*, Wyd. LEX, Warsaw 2013, p. 14, 122.

Chapter 2.

THE ORGANIZATION AND FUNCTIONING OF SELECTED CITIES IN POLAND – CASE STUDIES

2.1. Municipal waste management in Poland – selected values and relations

It is assessed that about 250 million Mg of municipal waste is generated in Europe every year[79]. Poland collected around 9.8 million Mg of municipal waste in 2004, in 206 – 11.6 million Mg. The forecasts as to the waste mass in 2020 and 2030 assume a significant increase, despite the anticipated drop in population in the national economic plan, especially in large Polish cities (Table 4).

In 2016, Poland generated 139,961,000 Mg of waste, 8.33% of which was constituted by municipal waste (11,654,000 Mg)[80]. The amount of municipal waste generated in the country in the last years has been increasing (Table 5) – in 2016, an increase of 7% was noted compared to the previous year. The ratio of amount of municipal waste generated per capita has also been increasing – from 282 kg in 2015 to 303 kg in 2016. Those values are significantly lower than the average ratio per capita in the EU in 2015 (474 kg).

[79] W. Melon, *Eksploatacja termicznego przekształcania odpadów*, "Komunalny Plus", 2015 issue 3.

[80] Protection of the Environment 2017, Central Statistical Office, Warsaw.

Table 4. General values that influence the expected changes in the supply of municipal waste

Change factor	Poland (2016-2030)	Małopolskie Voivod. (2016-2028)
Population prognosis	By 2030, an increase by approx. 300,000 (by 2.1%). Constant decrease in population in cities. Negative natural growth of 0.2% per year.	Decrease by approx. 22,000 (by 0.64%).
Predicted amount of generated waste	Two ratios were assumed in the forecast: 0.6% per year (low ratio) assuming a rate of natural growth of -0.15% per year and 1% (high ratio). Predicted amount of collected waste on average by 7.34% compared to 2014 (9.2% for a high hypothesis and 5.5% for a low hypothesis). Average predicted increase in generated waste by 2030 (compared to 2014) 10.89% per year.	Increase in the unit ratio of generated municipal waste by 1% per year by 2020. Increase in the unit ratio of generated municipal waste by 0.5% per year in the period of 2021-2028.
Economic package with closed circulation	Achieving a municipal waste recycling ratio of 65% by 2030. Achieving a packaging wastes recycling of 75% by 2030. Reduction in storage of waste to maximum 10% by 2030.	Minimization of mass of waste from thermal processes – slag, ash (large amount of accumulated waste of this type in the previous years – recommended storage of such waste).

Source: own analysis based on: Resolution no. 88 of the Council of Ministers dated 1 July 2016 on the national waste management plan for 2022, Official Journal of the Republic of Poland 2016, item 784 and Waste management plan for Małopolskie Voivodeship for the period of 2016-2022, Resolution no. XXXIV/509/17 of the Local Government Assembly of Małopolskie Voivodeship dated 27 March 2017.

The basic method of treatment of municipal waste was depositing it at landfill sites – in 2016, 37% of the total amount (i.e. 4.3 million Mg) was intended for storage. For municipal waste: recycling covered 28% (3.2 million Mg), thermal disposal at incineration plants – 19% (2.3 million Mg), biological processing – 16% (1.9 million Mg) (Table 5). For comparison – in the case of general amount of generated municipal waste in the EU: 29% was subjected to recycling, 27% disposed on with thermal methods, 26% disposed of through storage, while 16% was subjected to composting[81].

[81] Protection of the environment 2017, Central Statistical Office, Warsaw.

The current dynamics of implementation of those standards has been illustrated in Chart 2. It helps noticing the strong side of the changes in the structure of municipal waste management, i.e. the clear decrease in dynamics of stored waste and its percentage in collected waste compared to the dynamics of the population and mass of collected waste. The weak side concerns higher dynamics of waste emission per capita compared to the dynamics of total population.

The mass of thermally converted waste and the percentage of thermally converted waste in the amount of collected waste features the highest dynamics, much higher than the mass of biologically converted waste (Chart 3), which directly results from the gradual increase in the capacity of thermal waste processing facilities launched in the period of 2014-2016.

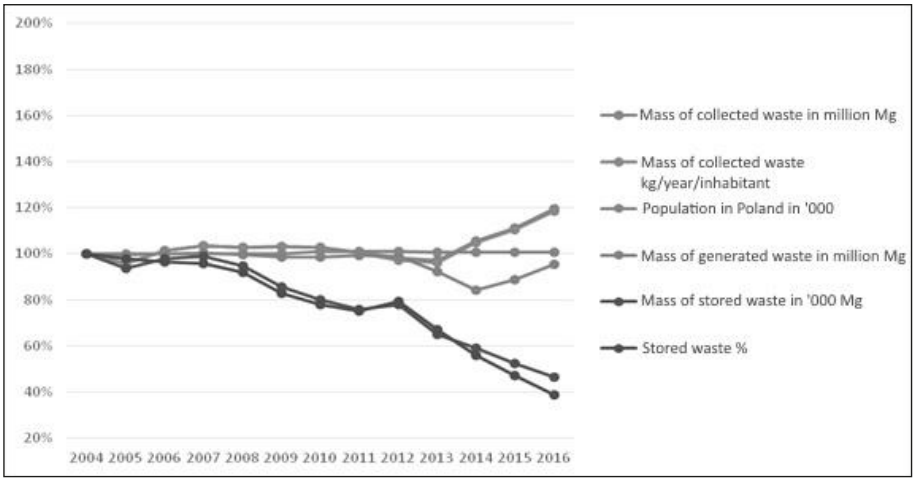

Chart 2. The dynamics of changes in the amount of generated waste and amount of stored waste in the context of population changes in Poland in the period of 2004-2016 (base year 2004)

Source: own analysis on the basis of data in Table 5.

Table 5. The structure of municipal waste in Poland in years 2004-2016

Specification	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Population in Poland [in '000]	38173.8	38157.1	38125.5	38115.6	38135.9	38167.3	38529.9	38538.4	38533.3	38495.7	38478.6	38437.2	38433.0
Dynamics* [%]	100.0	100.0	99.9	99.8	99.9	100.0	100.9	101.0	100.9	100.8	100.8	100.7	100.7
Mass of collected waste, million Mg	9.8	9.3	9.9	10.1	10.0	10.1	10.0	9.8	9.6	9.5	10.3	10.9	11.7
Dynamics* [%]	100.0	95.8	101.2	103.3	102.9	103.0	102.9	100.7	98.2	97.0	105.5	111.3	119.4
Mass of collected waste [kg/year/inhabitant]	256	245	259	265	263	264	263	257	249	246	268	283	303
Dynamics* [%]	100.0	95.7	101.2	103.5	102.7	103.1	102.7	100.4	97.3	96.1	104.7	110.5	118.4
Mass of generated waste [million Mg]	12.23	12.17	12.24	12.26	12.19	12.05	12.04	12.13	12.09	11.30	10.30	10.86	11.65
Dynamics* [%]	100.0	99.5	100.1	100.2	99.7	98.5	98.4	99.2	98.9	92.4	84.2	88.8	95.3
Mass of thermally converted waste ['000 Mg]	87.4	44.4	45.3	41.0	62.7	101.1	102.5	98.3	50.7	766.0	1560	1439	2266.3
Dynamics* [%]	100.0	50.8	51.8	46.9	71.7	115.7	117.3	112.5	58.0	876.4	1784.9	1646.5	2593.0
Thermally converted waste [%]	0.89	0.47	0.46	0.41	0.62	1.00	1.02	1.00	0.53	8.08	15.1	13.2	19.4
Dynamics* [%]	100.0	52.8	51.7	46.1	69.7	112.4	114.6	112.4	59.6	907.9	1696.6	1483.1	2179.8
Mass of biologic. processed waste ['000 Mg]	234	318	297	278	262	508	608	366	926	1230	1154	1750	1890
Dynamics* [%]	100.0	135.9	126.9	118.8	112.0	217.1	259.8	156.4	395.7	525.6	493.2	747.9	807.7

Biologically processed waste, %	2.39	3.39	3.01	2.75	2.61	5.06	6.06	3.72	9.67	12.99	11.17	16.10	16.20
Dynamics* [%]	100.0	141.8	125.9	115.1	109.2	211.7	253.6	155.6	404.6	543.5	467.4	673.6	677.8
Mass of stored waste ['000 Mg]	9194	8623	8986	9098	8693	7859	7369	6967	7158	5979	5437	4,808	4255
Dynamics* [%]	100.0	93.8	97.7	99.0	94.6	85.5	80.2	75.8	77.9	65.0	59.1	52.3	46.3
Stored waste [%]	94.21	92.18	90.99	90.24	86.62	78.18	73.36	70.89	74.71	63.11	52.63	44.30	36.50
Dynamics* [%]	100.0	97.8	96.6	95.8	91.9	83.0	77.9	75.2	79.3	67.0	55.9	47.0	38.7
Waste subjected to thermal conversion, biological processing, and storage, [% of collected waste]	97.49	96.04	94.46	93.40	89.85	84.24	80.44	75.61	84.91	84.18	78.90	73.60	72.10
Mass of recycled waste ['000 Mg]	245	365	551	663	1022	1581	1960	2399	1445	1495	2149	2863	3239
Recycled waste [% of collected waste]	2.51	3.96	5.54	6.60	10.15	15.76	19.56	24.39	15.09	15.82	21.10	26.40	27.90

* Dynamics (2004 = 100%).

Source: own analysis based on: The communal infrastructure in 2016, Central Statistical Office, Warsaw 2017, and Resolution no. 88 of the Council of Ministers dated 1 July 2016 on the national waste management plan..., op. cit.

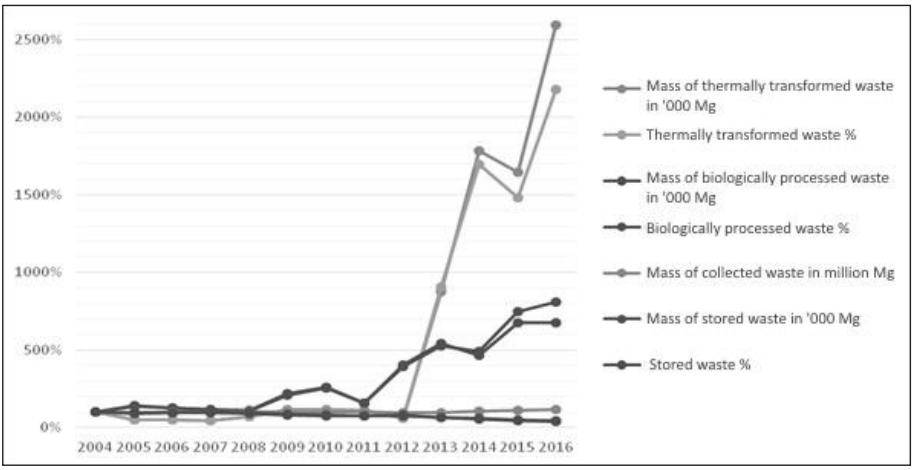

Chart 3. Dynamics of changes in amount of thermally and biologically processed waste and stored waste in years 2004-2016 (base year 2004)

Source: own analysis on the basis of data in Table 5.

Facilities

Table 6 has presented the amount of collected municipal waste and number of regional facilities of respective types along with their capacities in individual voivodeships in 2016. According to the data in the Provincial Waste Management Plan, in 2016, there were 157 MBP facilities with a total capacity of the mechanical part of 10,812,000 Mg/year. 97 green RIPOK facilities operated, collecting 873,300 Mg of waste. There functioned 144 landfill sites with a total capacity of 61,015,800 m^3.

KPGO 2022 assumes that in 2022 the mass of mixed municipal waste will be 7,426,200 Mg and there will be 179 MBP facilities with a total capacity of mechanical processing reaching as high as 12,141,100 Mg/year, which gives a capacity surplus of 4,714.9 Mg/year. These assumptions do no fully indicate a thoughtful municipal waste management system, since there is no justification for the extension and maintenance of MBP facilities in a situation of a probable significant shortage of waste compared to the capacities.

In Poland (as of the end of 2018), there are 7 municipal waste incineration plants (in 2016, there were 6 such facilities with a total capacity of 884,000 Mg per year – Table 6). The oldest plant, located in Warszawa-Targówek, was

launched in 2001 as the Solid Municipal Waste Utilization Plant[82]. At the turn of 2015/2016, 4 large facilities were launched: in Bydgoszcz, Cracow, Konin, and Białystok. In 2017, an incineration plant in Poznań was launched, in 2018 – in Szczecin. The current total capacity of municipal waste incineration plants is (as of the end of 2018) 1,034,000 Mg/year. There is another waste incineration plant in start-up stage in Rzeszów – with an intended capacity of up to 100,000 Mg/year. The facility in Warsaw will be expanded – two new lines will be constructed; the total capacity of the plant will increase to 300,000 Mg/year. All the incineration plants in Poland (both opened and under construction) apply the technology of incineration on grate, the most common method in the world, verified and reliable.

KPGO 2022 assumes that thermal transformation should not cover more than 30% of generated municipal waste. The act dated 19 July 2019 on amendment to the act on maintaining cleanliness and order in commune and certain other acts introduced Art. 35b in the act on waste, which confirms the principle of 30% ("Percentage of the mass of thermally converted municipal waste and waste originating from municipal waste processing in the country compared to the mass off generated municipal waste in the country must not exceed 30%")[83]. The current capacity of incineration plants ensures about 9% incineration of municipal waste estimated for 2030. The value is lower than in Great Britain, Italy or Portugal, where about 20% of collected municipal waste is incinerated and much lower than in Denmark and Sweden where over 50% of such waste is incinerated. In Germany, the majority of waste is thermally transformed and used for power generation[84].

However, the problem is not about a high percentage of incinerated municipal waste but about a rational management of such waste. The supply of waste for incineration depends on many factors, including the heating value and the available technology and functioning of other municipal waste management facilities, and standards regulated in this scope. The 30% limit for municipal waste deployed to incineration plants mainly results from the necessity of meeting

[82] T. Pająk, *ZUSOK - Ochrona klimatu, źródło energii*, VI Forum Operatorów Systemów i Odbiorców Energii i Paliw, Bezpieczeństwo energetyczne a nowe kierunki wytwarzania i wykorzystania energii w Warszawie, Warsaw 2009.

[83] Act dated 19 July 2019 on amendment to the act on maintaining cleanliness…, op. cit.

[84] W. Melon, *Eksploatacja termicznego przekształcania odpadów*, op. cit.

the increased requirements regarding the level of recycling of some fractions of municipal waste, which will be impossible in the case of large streams of mixed waste deployed to incineration plants. That is why provincial waste management plans in 2016 have assumed that the planned new facilities for thermal conversion of waste in the perspective of the period until 2022 would be mainly adjusted to incineration of the fuel fraction left after selection of other fractions desired in recycling (i.e. RDF or the so-called pre-RDF). According to the provincial plans for the period until 2022, 68 new facilities are to be launched (in the case of Warsaw – new lines in the existing incineration plants) with a total capacity of about 2 million Mg/year.

The next sub-chapter has discussed the examples of municipal waste management systems in several Polish. Four cities were selected – two large (Cracow and Białystok), one medium-size (Koszalin), and one small (Nowy Targ). Cracow is a city of metropolitan character; the commune entrusted the company MPO, in the in-house mode, with managing the municipal waste management system that is viewed as model and complete, while the waste incineration plant (operating since 2016) closed the circulation of waste in Cracow. Białystok is also a voivodeship capital; it applies the in-house model, but several facilities operate outside that mode. Koszalin is a medium-size city in a voivodeship featuring lower development level of municipal waste management that has no major facilities for it like, e.g. incineration plants. Nowy Targ is an example of a small city, located in the tourist region of Podhale, featuring stricter environmental standards, with predominance of private facilities that serve not only the inhabitants of the city area, but also of neighboring communes. Both Koszalin and Nowy Targ apply the market (tender) model of entrusting public tasks regarding municipal waste management.

Table 6. Existing municipal waste facilities in Poland in 2016

Voivodeship	Number of regions	Amount of mixed municipal waste '000 Mg/year	Number of MBP facilities	Capacity of mech. part of MBPs '000 Mg/year	Capacity of biol. part of MBPs '000 Mg/year	Number of landfill sites	Landfill capacity in '000 m³	Number of "green RIPOKs"*	Capacity of "green RIPOKs" '000 Mg/year*	Number of Municipal Waste Thermal Processing Plants (ITPOK)	ITPOK capacity '000 Mg/year
Dolnośląskie	6	826.0	17	1336.8	624.4	14	8126.0	22	91.7	0	0
Kujawsko-pomorskie	4	456.8	13	788.5	325.8	13	7149.9	10	73.0	1	180
Lubelskie	8	310.8	8	422.9	152.3	5	1216.9	2	3.5	0	0
Lubuskie	4	276.5	8	391.5	201.1	10	3572.7	5	76.8	0	0
Łódzkie	3	496.4	7	403.5	194.5	5	2263.4	3	4.9	0	0
Małopolskie	1	709.1	15	658.4	325.9	11	4161.3	10	118.0	1	220
Mazowieckie	4	1294.8	12	1850.5	880.4	7	4256.9	4	96.8	1	60
Opolskie	4	214.4	5	426.0	166.0	9	1795.8	4	10.0	0	0
Podkarpackie	6	337.1	6	288.0	132.0	3	1540.3	3	13.2	0	0
Podlaskie	4	235.1	7	227.7	133.2	5	994.7	6	14.0	1	120
Pomorskie	4	579.9	10	782.6	280.8	11	4303.7	10	191.0	0	0
Śląskie	3	1056.4	17	1168.3	572.9	20	9366.5	4	37.5	0	0
Świętokrzyskie	6	167.7	6	200.8	77.3	8	2554.8	6	19.4	0	0
Warmińsko-mazurskie	5	361.1	7	583.0	212.0	8	3043.1	0	0.0	0	0
Wielkopolskie	10	904.0	8	581.2	268.6	10	3478.0	3	73.0	2	304
Zachodniopomorskie	2	486.1	11	702.5	325.7	5	3191.8	5	50.5	0	0
TOTAL	74	8712.2	157	10812.2	4872.9	144	61015.8	97	873.3	6	884

* Data for 2014.

Source: of analysis based on the Provincial Waste Management Plan, National Waste Management Plan, Central Statistical Office Protection of the Environment 2017; and G. Wielgosiński, O. Namiecińska, P. Saladra, *Termiczne przekształcanie odpadów komunalnych w Polsce w* świetle *nowych planów gospodarki odpadami*, "Nowa Energia", 2017 issue 2.

2.2. The integrated municipal waste management system in Cracow

General information

The city of Cracow, which is the seat of the authorities of Małopolskie Voivodeship, is located in southern Poland, on the Vistula River. It is the second largest Polish city, both in terms of size and population. The area covered by the Municipal Commune of Cracow is 326.9 km^2, while the total number of inhabitants, according to the data of the Central Statistical Office for 2016, amounts 765,320[85]. In 2016, population density reached 2341 people/km^2.

The self-governmental model of city cleaning

Cracow developed a self-governmental Polish model of city cleaning, which had its 150th anniversary in May 2017. The letter of King Sigismund I the Old dated 1533 states the following: "The city of Cracow is magnificent… yet carelessly and despicably managed and maintained". At some point, the city authorities took action and on 24 August 1884 adopt the Rules of cleanliness and order in the capital, royal city of Cracow, approved by the city council and signed by the then president Ferdynand Weigl[86].

In 1906, the self-government of Cracow established the City Cleaning Plant which conducted the cleaning activities in Cracow and would remain under the authority of the city until 1950. Municipal waste management went through a nationalization process in the period of 1951-1933; on 2 February 1951, the pre-war City Cleaning Plant was transformed into the Municipal Cleansing Service (MPO) (by the Presidium of the National Municipal Council in Cracow, under the supervision of the minister of municipal management and the direct supervision of the National Municipal Council in Cracow).

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[85] stat.gov.pl/statystyka-regionalna/rankingi-statystyczne/miasta-najwieksze-pod-wzgledem-powierzchni/ (DOA 25.11.2018) and Central Statistical Office, *Ludność. Stan i struktura oraz ruch naturalny w przekroju terytorialnym* 2017.

[86] J.M. Małecki, *Prehistoria. Zanim powstał Zakład Oczyszczania Miasta w Krakowie. Oczyszczania Krakowa od czasów najdawniejszych do 1906 r.*, in: *Historia i współczesność 1906-2006*, MPO Sp. z o.o., Cracow 2007.

In 1970, by way of an agreement between MPO and the Wieliczka Salt Mine, works were commenced to establish the Barycz landfill site. MPO participated in the implementation of a new social and economic policy – new equipment, new waste export methods, new environmental standards, technical and technological modernization of the cleaning process and the MPO headquarters, new demands, new markets, competition and changes in the status of the department.

Gminna Spółka Komunalna MPO Sp. z o.o., entered into the court register on 23 November 1993 as a commercial law company, renders services for the city of Cracow, the commune of Cracow, and neighboring communes. It modernizes the Barycz landfill site, builds and administers new municipal waste management facilities.

MPO Sp. z o.o. implements the environmental policy within the scope of municipal waste management in the municipal commune. By resolution dated 9 October 1996, the City Council of Cracow established the most crucial directions in the municipal waste management of the city. By adopting the resolution, the Cracow self-government expressed their intent to provide a comprehensive solution to the problem of municipal waste. It also provided the City Board with instructions regarding the program of implementation activities.

In 1996, elaboration of a long-term variant municipal waste management program for the commune of Cracow was commissioned in order to ensure living conditions for the city inhabitants and to create a cleaner and healthier image of the city. On 10 June 1998, the City Council of Cracow reviewed the variants proposed by authors of the study and opted for a variant of waste management would involve:

- expanding the Barycz municipal waste landfill site by the 3rd stage,
- constructing a composting plant,
- expanding the system of selective collection of waste along with construction of waste sorting plants,
- constructing a thermal waste utilization plant.

With respect to the limited capacity of the part of the Barycz landfill site exploited at that time, MPO Sp. z o.o. commenced its search for financing sources to construct municipal waste management structures. One of the initiatives of the European Union member states was utilized, i.e. the ISPA Fund (*Instrument for Structural Policies for Pre-Accession*). It covered the sectors of protection of the environment and transport and was intended to support investment projects that contributed to elimination of the discrepancy between standards and practices used in candidate countries and the standards and practices applicable in the EU member states.

Entrusting Miejskie Przedsiębiorstwo Oczyszczania Miasta MPO Sp. z o.o. with management over the integrated municipal waste management system (ZGOK)

On 1 January 2013, the act on maintaining cleanliness and order in communes was amended[87]. Consequently, the municipal commune of Cracow assumed the statutory liability for organization and functioning of the system for collection and management of municipal waste generated by real property located within its territory, including liability for achieving ratios of recovery of waste for reuse stipulated in the act.

Management of municipal waste in the municipal commune of Cracow has been regulated by resolutions of the City Council of Cracow, including, among others, the Terms and conditions regarding maintaining cleanliness and order within the territory of the municipal commune of Cracow[88].

The City Council of Cracow entrusted MPO Sp. z o.o. with the duty of administering the integrated municipal waste management system[89]. The principles regarding the entrustment of obligations of the municipal commune of Cracow to MPO Sp. z o.o. were provided for in the executive agreement concluded on 7 June 2013.

As part of the duties assumed by MPO Sp. z o.o. under the concluded executive agreement, one should highlight the following:

- ensuring management of municipal waste at facilities that allow fulfillment of the obligations arising from Art. 3b and 3c of the act on maintaining cleanliness and order in communes (with regard to, i.a. levels of recycling) imposed on the commune,
- ensuring financing, construction, maintenance and exploitation of regional municipal waste processing plants, including comprehensive management of the investment implementation process in connection with construction, extension, maintenance and exploitation of the existing and new regional municipal waste processing plants, except for facilities implementation of which has been entrusted to other entities,
- ensuring that the levels of recycling, preparation to reuse, recovery with other methods, and limitation of mass required by law have been achieved.

[87] Polish Journal of Laws 2011 no. 152 item 897.

[88] Resolution no. XLVII/846/16 of the Council of the City of Cracow dated 8 June 2016.

[89] Resolution no. LII/697/12 of the Council of the City of Cracow dated 11 July 2012.

Structure of the Integrated Municipal Waste Management System in Cracow

The President of the city of Cracow entrusted management of waste in Cracow to Miejskie Przedsiębiorstwo Oczyszczania Miasta Sp. z o.o. through the in-house mode, retaining the right to supervise, coordinate and control the efficiency of the process. The Municipal Council of Cracow decided to divide the city into five sectors of waste collection, assigning each sector with 3-4 districts (Table 7, Diagram 4).

Table 7. Sectors of municipal waste management in Cracow (data for the second half of 2014)

Sectors	District nos.	District names	Structure of number of inhabitants, [%]	Structure of supply of waste, [%]	Supply of municipal waste, kg per year per capita
I	I, II, III, XIV	Stare Miasto, Grzegórzki, Prądnik Czerwony, Czyżyny	20	19	308
II	IV, V, VI, VII	Prądnik Biały, Krowodrza, Bronowice, Zwierzyniec	21	25	400
III	VIII, IX, X	Dębniki, Łagiewniki-Borek Fałęcki, Swoszowice	13	14	344
IV	XI, XII, XIII	Podgórze Duchackie, Bieżanów-Prokocim, Podgórze	21	22	366
V	XV, XVI, XVII, XVIII	Mistrzejowice, Bieńczyce, Wzgórza Krzesławickie, Nowa Huta	25	23	304
Total	18 districts	X	100	100	342

Source: J. Famielec, *Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym*, op. cit., p. 127.

MPO Sp. z o.o., as the administrator of the Integrated Municipal Waste Management System in the commune of Cracow:

- prepares and provides the commune with drafts of and amendments to resolutions within the scope of the municipal waste management system,
- manages the system for submitting statements on fees for municipal waste management system,
- ensures management of municipal waste at relevant facilities (including own facilities: waste collection point, Barycz waste landfill site, composting plant, sorting plant),

- prepares and conducts the tendering procedure for collection of municipal waste from real property owners and for waste management,
- supervises the implementation of duties entrusted to entities that collect municipal waste from real property owners and to entities managing municipal waste, as well as supervises the fulfillment of real property owners' obligations as to the appropriate management of municipal waste,
- manages points of selective collection of municipal waste,
- coordinates and conducts informative and educational activities within the scope of proper management of municipal waste, especially with regard to selective collection of municipal waste,
- performs the annual analysis of the condition of municipal waste management in order to verify the technical and organizational capacities of the municipal commune of Cracow within the scope of management of municipal waste.

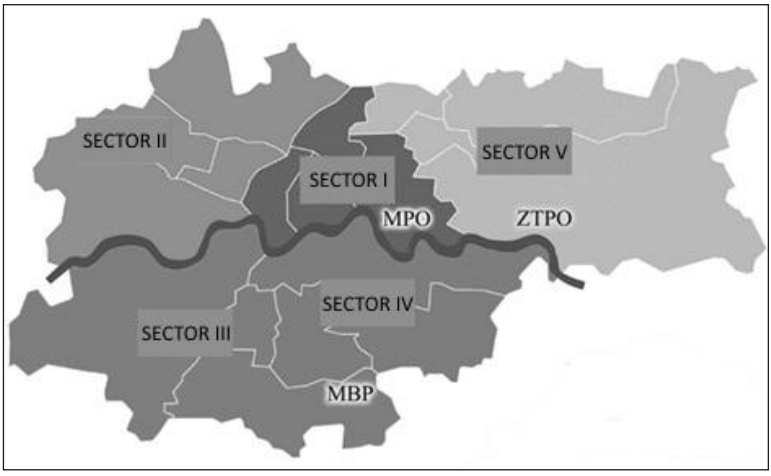

Diagram 4. Division of the city of Cracow into sectors of waste collection, including the indicated localization of waste management circulation

Source: J. Famielec, *Gospodarka odpadami komunalnymi jako działalność gospodarcza realizowana w ogólnym interesie gospodarczym*, op. cit., p. 136.

Nowadays, MPO Sp. z o.o., as the administrator of the Integrated Municipal Waste Management System in Cracow, has the authority over all the communal facilities for processing and managing waste, except for the Thermal Waste Conversion Plant (Zakład Termicznego Przekształcania Odpadów, in short: ZTPO), which

also receives waste as part of the Integrated Municipal Waste Management System in the municipal commune of Cracow. Waste accumulated within real properties in the municipal commune of Cracow is collected by entities appointed through tendering procedure for public procurement and transported to municipal waste processing facilities designated by MPO Sp. z o.o. (Diagram 5).

Entities and facilities of municipal waste management in Cracow have been concentrated in three sectors (see Diagram 4). Sector I involves the system administrator (MPO Sp. z o.o.) and their facilities and points of selective collection of waste. Sector III includes the complex of the Barycz Ecological Center, with a facility for mechanical and biological processing of waste (MBP), a landfill site, a sorting plant, and a composting plant. Sector V, in the district of Nowa Huta, has finalized the construction of ZTPO – the last, missing link in the integrated municipal waste management system in Cracow.

The system used to manage the municipal waste in Cracow requires further enhancements, yet it already has met the general premises of the paradigms regarding sustainable municipal waste management in large cities (with features of major urban areas). In particular, such balance has been safeguarded thanks to the Thermal Waste Conversion Plant (called the Eco-Incineration Plant) launched in 2016.

Waste streams and their management

The number of people served by the Integrated Municipal Waste Management System in Cracow does not only include permanent inhabitants (population at the end of 2016 was 765,320), but also people working within the municipal commune of Cracow, commuters from neighboring communes, and a vast number of students estimated at approx. 185,000[90].

The amount of municipal waste collected in the municipal commune of Cracow in the period of 2013-2017 has been presented in Table 8. The waste accumulation ratio in Cracow in 2016 amounted 419 kg/inhabitant/year. The ratio acknowledges only permanent residents of Cracow (according to data of the Central Statistical Office). It is noticeably higher than the average ratio in 2014, which amounted 342 kg/inhabitant/year (see Table 7).

[90] Analysis of the municipal waste management in the municipal commune of Cracow in 2016 (Revision).

Table 8. Amount of waste collected as part of the Integrated Municipal Waste Management System in Cracow in 2013-2017

No.	Specification	Amount of waste [Mg]				
		since 1 July 2013	2014	2015	2016	2017
I	Unsorted (mixed) municipal waste	101,445.7	186,457.4	191,769.1	206,187.7	214,679.4
II	Waste collected selectively, including:	28,850.4	107,332.3	118,564.5	114,336.6	121,105.3
1	Selectively collected municipal waste (so-called dry fraction)	21,230.9	70,371.6	73,171.5	66,757.5	67,076.3
2	Selectively collected large-size waste	3,009.9	16,223.3	15,818.0	14,593.5	17,017.5
3	Selectively collected green waste	4,342.8	15,630.3	24,227.6	27,782.2	30,482.3
4	Selectively collected biodegradable kitchen waste	266.7	891.2	1,347.8	1,880.8	2,729.5
5	Rubble		4,215.84	3,999.4	3,322.4	3,799.7
	Total	**130,296.2**	**293,789.8**	**310,333.7**	**320,524.3**	**335,784.8**

Source: own analysis according to information from MPO Sp. z o.o. and the Analysis of the condition of municipal waste management in the municipal commune of Cracow in 2017.

The share of specific methods of waste management in the municipal commune of Cracow in the period of 2016-2017 has been presented in Table 9. One should highlight the decrease in share of the stream of waste deployed to recovery and the increase in the stream deployed for thermal conversion. It is the consequence of the necessity to ensure an adequate size of the waste stream intended for incineration in a situation in which ZTPO is not capable of accepting waste originating from the outside of the municipal waste of Cracow (which results from contracts on the subsidy for construction of the incineration plant).

Table 9. Share of specific methods of waste management in the municipal commune of Cracow in the period of 2016-2017 [%]

Specification	2016	2017
Recycling	9.26	9.62
Recovery	68.22	55.65
Thermal waste disposal	22.41	33.86
Disposal through storage	0.11	0.87

Source: information acquired from MPO Sp. z o.o.

Levels of recycling and preparation to reuse of the raw material fraction, recycling and preparation to reuse and recovery with other methods with regard to construction and renovation waste, as well as the amount of biodegradable waste deployed for storage in the period of 2014-2017 have been presented in Table 10. In 2017, there was a marginal decrease in the level of recycling of the raw material fraction compared to the ratio in 2016; in the following years, the level should increase, i.a. due to modernization of the sorting plant for selectively collected wasted finalized in 2018. One should also bear in mind that since 2016, storage of biodegradable waste has been basically eliminated, thanks to the launch of ZTPO in Cracow.

Table 10. Levels of recycling and preparation to reuse waste that were achieved in the municipal commune of Cracow in years 2014-2017

Specification	2014	2015	2016	2017
Level of recycling of raw material waste [%]	19.66 [min. 14]	27.36 [min. 16]	33.02 [min. 18]	32.10 [min. 20]
Level of recycling of construction and demolition waste [%]	39.6 [min. 38]	100 [min. 40]	97.47 [min. 42]	100 [min. 45]
Level of amount of biodegradable waste sent to be stored [%]	16.8 [max. 50]	14.9 [max. 50]	0 [max. 45]	0.04 [max. 45]

Source: Revision of the report of the President of Cracow on the implementation of tasks within the scope of municipal waste management in years 2014, 2015, 2016, 2017.

Income of the commune of Cracow on the fee for municipal waste management

Residential real properties in the municipal commune of Cracow adopt a fee calculation system in which the fee is charged per household, whereby the rate of the fee is determined on the number of householders declared in a relevant statement. The current rates have been presented in Table 11. In the case of uninhabited real properties, the fee is charged based on the number of waste containers. In the case of partially inhabited and partially uninhabited real properties that generate municipal waste, the charged fee is determined by the number of waste containers.

Table 11. Monthly rates of fees for management of municipal waste in the municipal commune of Cracow [PLN]

Household	Single-family development		Multi-family development	
	Waste collected selectively	Waste collected non-selectively	Waste collected selectively	Waste collected non-selectively
one person	26.00	39.00	15.00	22.00
two people	36.00	54.00	29.00	41.00
three people	46.00	69.00	41.00	60.00
four people	56.00	84.00	50.00	73.00
five people	63.00	94.00	56.00	82.00
six people	66.00	99.00	59.00	86.00
seven people and more	69.00	103.00	62.00	89.00

Source: Resolution no. LXIX/996/13 of the Council of the City of Cracow dated 13 March 2013 on selection of the method for determination of the fee for municipal waste management and determination of the rate of such fee.

The availability of financial data on the functioning of municipal waste management in the commune is limited and not covered by systemic reporting. Table 12 has presented the proceeds from the said fee in years 2013-2018. It has only acknowledged selected data, yet they confirm growth of the system through:

- a clear increase in the number of (household) statements covered by the system, from about 50,800 in 2013 to over 61,000 in the first quarter of 2018,
- a high enforceability rate of the payable fee (almost 100%), an increase in yearly proceeds on fees from PLN 166 million to over PLN 185 million in 2017, with stabilized average charge per single statement at level of approx PLN 3,000 per annum.

Table 12. Proceeds from the fee for municipal waste management in the commune of Cracow

Year	Proceeds from the fee in million PLN	Fee enforcement rate [%]	Number of statements	Average income per 1 statement in PLN
2013	94,250.97	96.9	50,799	1,855.37
2014	166,308.24	100.7	51,594	3,223.40
2015	170,065.35	100.1	54,688	3,109.73
2016	175,867.66	100.1	57,530	3,056.97
2017	185,311.37	99.9	60,509	3,062.54
2018 (Q1)	49,105.85	102.8	61,239	801.87

Source: data of the Municipal Office of the City of Cracow – own analysis.

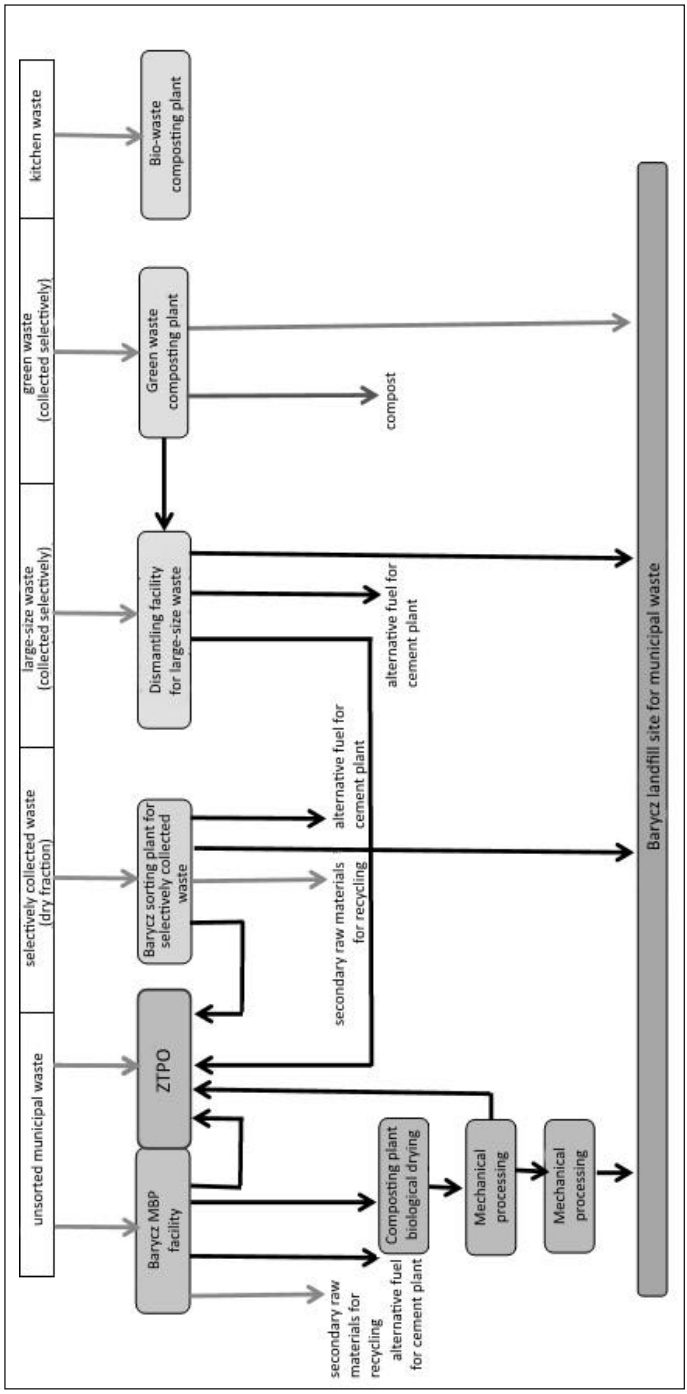

Diagram 5. Circulations between facilities in the municipal waste management system in Cracow – the current state

Source: own analysis based on data provided by MPO Sp. z o.o.

Barycz Ecological Center[91]

The Barycz Ecological Center is a complex of cooperating municipal waste management facilities administered by MPO Sp. z o.o. in Cracow, located within the post-exploitation areas of the "Wieliczka" Salt Mine situated within the territory of the municipal commune of Cracow. The beginnings of activities connected with management of municipal waste within this area originated from the demand for rehabilitation of lands degraded due to the exploitation of the mine. At the beginning of the 1970s, the lands were used to establish a landfill site for municipal waste from Cracow. The use of the first section of the landfill site commenced in 1974. Currently, due to numerous investments aimed at limiting the hazards connected with waste management and at enhancing the recycling and recovery ratios, the Barycz Ecological Center is comprised of the following structures:

- an MBP facility,
- a sorting plant for selectively collected municipal waste,
- a landfill site for municipal waste,
- a point of selective collection of municipal waste (PSZOK),
- a facility to produce electricity and heating energy using biogas,
- a green waste composting plant,
- a didactic path.

In 2014, the MBP facility was expanded with a sorting plant with a completely automated and unmanned technological line facilitated with optical, ballistic separators as well as separators for ferrous and non-ferrous metals. They allow extracting the highest possible number of fractions capable of being recovered or recycled from the stream of waste. The alternative fuel production hub is capable of processing waste that cannot be subjected to recycling into alternative fuel used as a source of energy at cement plants.

The process of biological processing of the undersize fraction (<80 mm), separated from mixed municipal waste at the mechanical section of MBP, is conducted in two stages. Initially, the waste is subjected to a biological process of drying in closed containers with active aeration (4 modules, 8 containers

[91] Based on a brochure titled "Centrum Ekologiczne Barycz" issued by MPO Sp. z o.o. in 2018; the waste management plan of Małopolskie Voivodeship..., op. cit.; information from MPO Sp. z o.o.; and *Instalacje przetwarzania odpadów komunalnych w Polsce – Informator i poradnik edukacyjny*, Regionalne Centrum Edukacji Ekologicznej, Płock 2014, pp. 141-148.

each). The process utilizes the heat generated during production of electricity using landfill biogas. Waste being the product of biological drying is stabilized in piles. Stabilized compost is deposited at the landfill site. The maximum capacity of the facility is 100,000 Mg/year for the mechanical section and 57,000 Mg/year for the biological section.

The Barycz composting plant, launched in 2005 and expanded in the period of 2012-2014, is intended for composting selectively collected green waste. It is a modular composting plant; closed containers are used for the initial stage of intensive composting. Then, the waste is stored in form of piles (periodically aerated through turning) and left for ripening. Good quality of output compost allows selling it as organic fertilizer (it has the permit of the Minister of Agriculture and Rural Development). The maximum capacity of the composting plant is estimated at 16,000 Mg/year.

The sorting plant for selectively collected waste was launched in 2006; its initial capacity was 20,000 Mg of dry fraction per year. Apart from an automatic metal separator, it employed the manual sorting method used to extract, among others, fractions such as waste paper (segregated as cardboard, illustrated magazines and newspapers, and paper mix), glass (segregated as colorless and colored), ferrous and non-ferrous metals, and plastic (segregated as colorless PET, colored PET, foil, and household chemistry packaging).

In 2017-2018, the sorting plant went through a thorough modernization as a result of which its current capacity is 55,000 Mg/year. To a large extent, the process has become automated; among others, optical separators for extraction of paper and plastic, ballistic separators or a separator of non-ferrous metals have been installed. The modernized technological sorting installation allows:

- sorting selectively collected waste of varying morphological content and percentage of undesired byproducts,
- separating recyclable raw material fractions from municipal waste,
- separating the remaining fraction and deploying it to the container loading station at which it is finally deployed for production of alternative fuel or thermal use,
- simultaneous and independent sorting of glass and other selectively collected waste (plastic packaging or paper) on two technological lines.

The Barycz municipal waste landfill site spans over a total area of approx. 36 ha and is divided into three stages, surrounded with 35-80 m wide

insulation green belts. 25 ha of land (stage I and II) has been currently closed, rehabilitated, and grassed. In 2005, the 3rd stage of the landfill site of 11 ha was handed over for exploitation. It was shaped as a recessed trough, intended to become an above-ground structure in the future. The bottom and the slopes of the trough were sealed and facilitated with a leachate drain system. Currently, the landfill site has been used only for storage of the stabilized compost generated at the MBP facility.

Biogas left at the landfill site is incinerated at four power generating units of a total power of 1.3 MW. The heating energy and electricity generated from biogas is used at the composting plant, for the biological processing of the undersize fraction, at the sorting plant, and at technical facilities of the landfill site, while the surplus of electricity is deployed to the power grid.

Large-size waste dismantling plant

The facility for dismantling large-size waste and electrical and electronic waste, along with an accumulation point located at the unit of MPO Sp. z o.o. in Cracow at ul. Nowohucka 1, was launched in June 2010. The facility is intended for collection, accumulation, generation (including processing), and recovery of waste through grinding and dismantling of large-size waste, electrical and electronic waste, as well as for tire shredding.

The technological line for mechanical grinding of waste, installed at the plant, is designed to grind large-size waste, such as: wooden and upholstered furniture, wood, plastic, etc. which later on is deployed to the cement plant as so-called alternative fuel. The technological line is comprised of, i.a. a system of shredders (initial, final), separators of ferrous and non-ferrous metals, an air separator.

The manual dismantling line is intended for dismantling electrical and electronic waste. For that purpose, work stands (workbenches) and cabinets facilitated with a complete set of tools necessary for dismantling are arranged along two lines of roller conveyors. Since this group of waste also includes used refrigerating appliances, the line is equipped with a work stand for extraction of freon and compressor oil. In the first place, in case of waste containing hazardous elements, hazardous materials or components are removed, i.e. elements with mercury, batteries and rechargeable batteries, cathode-ray tubes, printed

circuit boards, printing cartridges, etc. The next phase involves extraction of metals, glass, plastic, etc. from such waste.

The car tire shredding line allows processing of tires into, above all, alternative fuel additive. Tires are shredded (cut into smaller pieces) with stationary hydraulic cutters in order to facilitate their further transport or allow further use at the alternative fuel production plant, after prior removal of wire from the bead with a hydraulic tire debeader.

The plant mainly receives waste from Cracow inhabitants as part of the large-size waste collection system applicable in the city or transported directly by the inhabitants.

Eco-Incineration Plant – Thermal Waste Conversion Plant managed by Krakowski Holding Komunalny S.A.

Krakowski Holding Komunalny S.A. (in short: KHK) is a single-person company of the municipal commune of Cracow. The company was established under the resolution of the City Council of Cracow in 1996. In 2008, also by way of a resolution by the Cracow City Council, it was entrusted with tasks regarding construction of a thermal waste conversion plant in Cracow[92].

KHK S.A. was founded as a tax capital group created under an agreement dated 3 December 1996. The group also includes: Miejskie Przedsiębiorstwo Energetyki Cieplnej Spółka Akcyjna in Cracow, Miejskie Przedsiębiorstwo Komunikacyjne Spółka Akcyjna in Cracow, and Miejskie Przedsiębiorstwo Wodociągów i Kanalizacji Spółka Akcyjna in Cracow. As a part of the tax capital group, KHK S.A. serves the function of the parent company within the scope arising from regulations of the act on corporate income tax.

KHK S.A. realized the project titled "The program of municipal waste management in Cracow" as a part of the project called Program Operacyjny Infrastruktura i Środowisko ("Infrastructure and the Environment" Operating Program). The key investment of the implemented project involved construction of a municipal waste incineration plant with the necessary infrastructure.

[92] Resolution no. LV/488/96 of the City Council of Cracow dated 10 July 1996 on establishment of Krakowski Holding Komunalny – Spółka Akcyjna and Resolution no. LVI/710/08 of the City Council of Cracow dated 5 November 2008 on amendment to Resolution no. LV/488/96 of the City Council of Cracow dated 10 July 1996 and on entrusting Krakowski Holding Komunalny Spółka Akcyjna with realization of the Thermal Waste Conversion Plant in Cracow.

The total implementation cost of the project amounts approx. PLN 673 million net. The subsidy granted from the Cohesion Fund for the implementation of the project is PLN 372 million (which stands for about 55% of eligible costs) under a subsidy agreement concluded on 20 April 2011 with the National Fund for Environmental Protection and Water Management. The equity contribution of KHK S.A., in the amount of approx. PLN 301 million, was covered from own funds and a loan of PLN 298 million from the National Fund for Environmental Protection and Water Management.

On 27 June 2016, ZTPO was granted the so-called take-over certificate. Thus, starting from that date, the facility is used by KHK S.A.

The Eco-Incineration Plant in Cracow is a model example, both in terms of realization of the project, as well as utilization of a public subsidy on the completion of the Integrated Municipal Waste Management System elaborated by the commune of Cracow. The plant has been facing problems with its largest opponent – environmentalists. So far, any major conflicts with ecologists have been settled. The process of organizing tenders and selecting the winning tender for this investment task was difficult and it may be used as a superb case study for learning the chances and threats on the side of construction services companies, their attitudes and behavior towards public procurement (e.g. submission of a tender by a bankrupt tenderer).

The contractor for construction of the Thermal Waste Conversion Plant was POSCO Engineering & Construction Co. Ltd. which concluded the contract with the president of Cracow on 31 October 2012. The project used the "design and build" formula. Construction works commenced on 6 November 2013 and lasted 2 years. On 19 November 2015, the District Building Control Inspector in Cracow issued a decision to issue a use permit for the facility; its operations were inaugurated on 3 December 2015. Since that date, the facility underwent a test run. The initial stage was to verify equipment and systems for proper installation, use of components, and expected performance. From 19 February until 26 April 2016, the facility was subjected to contractual tests that lasted for 8 weeks; during that period, it would operate at its maximum capacity and be exposed to heavy loads. After contractual tests, the facility completely ceased its operation for inspection purposes. On 12 May 2016, the plant was reactivated upon safety tests conducted by the Office of Technical Inspection. After all the tests, the Office of Technical Inspection issued a relevant certificate.

On 23 May 2016, the Local Government Assembly granted the Thermal Waste Conversion Plant in Cracow, by way of resolution, the status of a Regional Municipal Waste Processing Facility (Polish abbreviation: RIPOK). On 27 June 2016, based on a take-over certificate issued by the Contract Engineer, Krakowski Holding Komunalny S.A. in Cracow became the owner of the Thermal Waste Conversion Plant. However, it must be highlighted that by 2021 (for a period of five years from the take-over by KHK S.A.), due to agreements concerning the subsidy for construction of the Eco-Incineration Plant, it can only accept waste from the municipal commune of Cracow, which has a major impact on the size of streams of municipal waste from the city that are deployed to respective facilities that manage them.

MPO Sp. z o.o. deploys to the Thermal Waste Conversion Plant municipal waste designated as 20 03 01 (mixed) and as 19 12 12, i.e. waste generated through mechanical processing (recovery) of selectively collected fractions of material, large-size, post-renovation, and packaging municipal waste. The incineration plant has two lines with a capacity of 14.1 Mg/h and a daily throughput of about 700 Mg. The designed yearly capacity of the facility is 220,000 Mg. The incineration plant is facilitated with a grate furnace integrated with a natural circulation boiler and an extraction-condensing turbine. The combustion system ensures keeping the exhaust temperature of over 2 seconds. The used combustion technology allows reducing the amount of pollutants in the combustion chamber and helps in adjusting the surplus of air thanks to secondary air recirculation. Reduction in the amount of nitrogen oxides is achieved through selective non-catalytic reduction with urea injection. Chlorine, sulfur and fluorine compounds are neutralized thanks to the semi-dry method of flue-gas desulfurization with limewash injection. Removal of total organic carbon, dioxins, furans and mercury vapor takes place through injection of dusty activated carbon. Particulates are filtered with bag filters. Operators of the incineration plant take measurements of seven pollutants in the exhaust and constantly measure the five parameters of exhaust. The incineration process generates secondary wastes: slag and bottom dust, boiler dust and fly ash, solid residues from exhaust after-treatment, as well as industrial wastewater. Slag and bottom ash will be prepared – through valorization (crushing, screening, seasoning in induction separators) – to be fully used for, e.g. road construction. Boiler dust, fly ash, and solid residues from exhaust after-treatment are stabilized and exported to landfill sites. Industrial

wastewater, pretreated in the in-house wastewater treatment plant, are discharged to the combined city sewer system. It is worth adding, that the Eco-Incineration Plant utilizes precipitation water for sanitary purposes and technological cooling. During the running-in period (December 2015 - May 2016), about 75,000 Mg of waste was incinerated, creating 15,500 Mg of slag and 3,450 Mg of ash. About 185,000 GJ of heating energy was generated for the city heating system, while the municipal power distribution system received approx. 19.5 GWh of electricity.

It is evaluated that such process of conversion of municipal waste at the Eco-Incineration Plant in Cracow brings the expected advantages: it reduces around 75% of the waste stream while preserving compliance with European environmental standards, ensures a high level of sustainability as to electricity and heating energy, as well as provides energy for the city. According to estimates, electricity produced by the Eco-Incineration Plant would be able to satisfy the power demand of Cracow trams and cover about 10% of the annual heat consumption in the city.

2.3. The model of municipal waste management in Białystok

General information

The city of Białystok, the seat of the authorities of Podlaskie Voivodeship, is located in north-eastern Poland. According to the data of the Central Statistical Office, the total population of Białystok in 2016 was 296,628 which, given the size of 102.12 km^2, translates to population density at 2,905 people/km^2. In 2016, Białystok was ranked 11 among largest Polish cities in terms of number of inhabitants[93].

Administration of the municipal waste management system

The city Białystok entrusted own duties of the commune of Białystok within the scope of comprehensive management of municipal waste and tasks

[93] stat.gov.pl/statystyka-regionalna/rankingi-statystyczne/miasta-najwieksze-pod-wzgledem-powierzchni/ (DOA 25.11.2018) and Central Statistical Office, *Ludność*…, op. cit.

concerning the city marketplace to PUHP LECH Sp. z o.o. (an entity of internal status, 100% owned by the commune of Białystok). The entrustment of own duties regarding the functioning of the municipal waste management system within Białystok followed the adoption of relevant resolutions by the City Council of Białystok (entrustment resolution – Resolution no. LI/603/13 dated 25 November 2013 amending the resolution on entrusting Przedsiębiorstwo Usługowo-Handlowo-Produkcyjne "LECH" Spółka z ograniczoną odpowiedzialnością in Białystok with tasks of the Commune of Białystok within the scope of recovery and disposal of municipal waste) and dispositions of the President of Białystok. The tasks, specified in detail in the executive agreement concluded between the city of Białystok and the company LECH have been listed in Table 13.

Table 13. Duties regarding municipal waste management entrusted to PUHP LECH Sp. z o.o. in Białystok

Duty areas	Duties
Administration of the municipal waste management system within the territory of Białystok	• designing, shaping and monitoring the municipal waste management system and ensuring and disposing the stream of municipal waste processed at facilities that belong to the city of Białystok, • organizing tenders for collection of municipal waste from real property owners and supervision over the quality of services within the scope of collection of municipal waste rendered by selected contractors, • supervision over real property owners within the scope of proper handling of municipal waste and adequate waste sorting, • managing statements on the rate of fee for management of municipal waste and performing activities arising from the statute of the tax authority (until September 2017), • performing the annual analysis of the condition of municipal waste management in order to verify the technical and organizational capacities of the commune of Białystok within the scope of management of municipal waste, • conducting activities connected with environmental education within the scope of proper handling of municipal waste.
Management of points of selective collection of municipal waste (PSZOK), includin stationary PSZOK facilities	Ensuring the functioning of two PSZOK facilities (within the area of the Municipal Waste Utilization Plant in Hryniewicze and MPO Białystok), the so-called nests (729 PCs within the city of Białystok) and units for collection of used electrical and electronic equipment (100 PCs)

Ensuring construction, maintenance and exploitaton of facilities for processing of municipal waste end entrusting, as part of the in-house mode, tasks at such facilities that concern processing of municipal waste originating from the area of Białystok	• exploiting and managing municipal waste at the Municipal Waste Disposal Plant (Polish abbreviation: ZUOK) in Białystok – a thermal municipal waste conversion facility (Polish abbreviation: ITPOK) that has the status of a regional facility, • using and managing municipal waste at the facility for mechanical and biological processing of municipal waste (MBP) located within the area of the Municipal Waste Utilization Plant in Hryniewicze which has the status of a regional facility, • exploiting and managing green waste at the Green Waste Composting Plant located within the area of the Municipal Waste Utilization Plant in Hryniewicze which has the status of a regional facility, • exploiting and managing selectively collected waste at the sorting plant for selectively collected waste located at the Municipal Waste Utilization Plant in Hryniewicze (a facility which uses optical separation – 17 optoseparators), • exploiting and managing WEEE at the Dismantling Facility for Waste of Electrical and Electronic Equipment, • exploiting and managing processes for management of post-production waste at the Municipal Waste Landfill Site (Field A – with the status of a RIPOK facility, currently a Municipal Facility, and Field B – intended for storage of waste generated in the process of thermal conversion of waste) located at the Municipal Waste Utilization Plant in Hryniewicze.

Source: executive agreement between the city of Białystok and PUHP LECH Sp. z o.o.

When realizing an EU-financed project titled "The integrated municipal waste management system for the agglomeration of Białystok", the main investment undertaking of which was construction of a thermal municipal waste conversion plant, the city of Białystok concluded agreements with 9 neighboring communes (so-called partnership communes). As part of the said agreements, partnership communes entrusted Białystok with communal duties within the scope of municipal waste management. Thus, the city of Białystok, under the a/m agreements, entrusted the task of managing municipal waste from partnership communes to a municipal company – PUHP LECH Sp. z o.o. Therefore, the entrustment of tasks within the scope of ensuring construction, maintenance, and exploitation of facilities and managing municipal waste at them covers communal duties of Białystok and of partnership communes.

Apart from entrusting tasks related to the functioning of the municipal waste management system within Białystok, the city of Białystok also

entrusted LECH with communal duties regarding marketplaces and market halls, the formal and legal aspects of which were regulated by the City Council of Białystok in Resolution no. XXVII/429/16 dated 28 November 2016 on entrusting Przedsiębiorstwo Usługowo-Handlowo-Produkcyjne "LECH" Spółka z ograniczoną odpowiedzialnością in Białystok with communal duties of the Commune of Białystok as to matters regarding marketplaces and market halls within the City Marketplace located at ul. Kawaleryjska in Białystok and also through signing an executive agreement providing a detailed specification of entrusted tasks and their financing.

Operations within the comprehensive municipal waste management system

The comprehensive municipal waste management system in Białystok covers, above all, selective collection of municipal waste from real property owners, processing of municipal waste according to the waste handling hierarchy, including the use of an advanced sorting plant for selectively collected waste (with the use of optical separation), a composting plant for management of green waste, and an incineration plant for processing of the so-called residual waste (mixed municipal waste and residues of the so-called high-energy fraction with combustion heat of 6 MJ/kg of dry mass). On behalf of the city of Białystok, the comprehensive municipal waste management system within the area of the city, both at administrative and operational level, i.e. within the scope of management of municipal waste, is administered by Przedsiębiorstwo Usługowo-Handlowo-Produkcyjne "LECH" Sp. z o.o.

As part of the comprehensive municipal waste management system, LECH Sp. z o.o. runs the operations of:

- the Municipal Waste Management System Office,
- the Municipal Waste Disposal Plant in Białystok (waste incineration plant),
- the Municipal Waste Utilization Plant in Hryniewicze (including the MBP facility, the Green Waste Composting Plant – RIPOK facility, the sorting plant for selectively collected waste, the point of selective collection of municipal waste – PSZOK, the Dismantling Facility for Used Electrical and Electronic Equipment, Storage Site A – a facility with the status of a RIPOK facility (currently being a Communal Facility), Storage Site B – residuals from the Thermal Municipal Waste Conversion Plant).

The system of municipal waste collection covers all real properties situated within the city, both inhabited (covered by virtue of the act) and uninhabited yet generating municipal waste (so-called uninhabited real property included into the system under the resolution of the City Council of Białystok).

It is estimated that about 75% of the created stream of municipal waste is generated by inhabited real properties, the remaining value of approx. 25% originates from uninhabited real properties. The number of households that municipal waste was collected from in 2016 equaled approximately 119,700. The number of real property owners who do not accumulate waste in the selective manner amounted less than 1%.

In order to organize collection of municipal waste from real property owners, the city of Białystok was divided into 6 sectors. Each sector constitutes a separate area in which the collection of municipal waste is performed by one removal company selected in an open tender. The system of accumulation and collection of municipal waste is handled in several ways. The general manner involves collection of mixed and raw material waste "at source" as well as selective collection of glass, green waste, furniture and large-size waste, ash and slag from domestic furnaces – the collection is performed in accordance with a set schedule. Moreover, there are the so-called nests (729 "nests" with containers for selective collection), two municipal PSZOK facilities and mobile units for collection of large-size waste and green waste.

Waste streams and their management

In 2016, a total of 98,297.78 Mg of municipal waste was collected, including 93,484.43 Mg collected directly "at source", 1,230.43 Mg at "nests", and 3,582.92 Mg at PSZOK facilities (Table 14). The accumulation rate for municipal waste in 2016 reached 332 kg/inhabitant/year.

Table 14. Amount of waste collected within the commune of Białystok in the period of 2014-2016 [Mg]

Specification	2014	2015	2016
Total municipal waste	95,923.7	100,187.3	98,297.8
Including:			
• mixed municipal waste	80,087.7	70,759.1	52,980.7
• total fractions of: paper and cardboard, plastic, metals and composite packaging	2,426.6	8,987.2	23,213.9

Source: an analysis of the state of municipal waste management within the commune of Białystok in 2016.

One should note a significant increase in the achieved level of recycling for the raw material fraction observed since 2015, an increased level of recycling for construction and dismantling waste – since 2016, and a noticeable reduction in the amount of biodegradable waste deployed for storage in 2016 and 2017, which has been illustrated in Table 15. Achieving such considerable ratios of environmental efficiency of the municipal waste management system was possible thanks to the advanced facilities launched in 2016, i.e. the sorting plant within the area of the Municipal Waste Utilization Plant in Hryniewicze and an incineration plant functioning as a part of the Municipal Waste Utilization Plant in Białystok.

Table 15. Levels of recycling and preparation to reuse of waste and levels of reduction in biodegradable waste deployed for storage within years 2014-2017 achieved in the commune of Białystok

Specification	2014	2015	2016	2017
Level of recycling of raw material waste [%]	19.77 [min. 14]	32.68 [min. 16]	34.68 [min. 18]	42.69 [min. 20]
Level of recycling of construction and demolition waste [%]	52.84 [min. 38]	41.44 [min. 40]	73.66 [min. 42]	77.02 [min. 45]
Level of amount of biodegradable waste sent to be stored [%]	48.77 [max. 50]	41.61 [max. 50]	8.60 [max. 45]	5.83 [max. 45]

Source: an analysis of the state of municipal waste management within the commune of Białystok in 2017.

The fee for management of municipal waste

The fee for municipal waste management, in the case of real properties, is charged per one household according to the floor area of the residential premises (up to 40 m^2, from 40 to 80 m^2, over 80 m^2). It is the so-called flat rate/floor area method (Table 16).

In the case of uninhabited real property, the charge is paid "per container" (i.e. the due amount is the product of the number of containers with waste generated by a particular real property and the rate per container provided for in the resolution of the city council).

Table 16. Rates of fees for inhabited real property charged for municipal waste management in the commune of Białystok in 2016

Specification	Waste accumulated and collected selectively by the household [PLN/month]	Waste accumulated and collected non-selectively for residential premises [PLN/month]
up to 40.00 m^2	9	23
from 40.01 m^2 to 80.00 m^2	21	42
over 80.00 m^2	29	54

Source: an analysis of the state of municipal waste management…, op. cit.

Municipal Waste Utilization Plant in Hryniewicze

The Municipal Waste Utilization Plant in Hryniewicze comprises of the following facilities:

- an MBP facility for processing of mixed municipal waste,
- a green waste composting plant,
- a landfill site.

Moreover, the complex in Hryniewicze serves for operations of:

- a sorting plant used for recovery by sorting selectively collected waste,
- a facility for processing of large-size waste and used electrical and electronic equipment,
- a point of selective collection of municipal waste (PSZOK),
- a landfill site for storage of residues from the thermal conversion plant for municipal waste (ITPOK).

The capacity of the mechanical section at the MBP facility is 120,000 Mg/year. Mechanical processing employs screening of the stream of municipal waste through a sieve, separating the ferromagnetic fraction from waste, and processing the fraction over 80 mm for waste recovery. The under-size fraction is deployed for the bio-stabilization process conducted for at least 10 days in 32 KNEER containers, with the use of automatic aeration and humidification. The second stage involves waste ripening in piles set within the technological yard (lasting about 6-8 weeks). Ripe stabilized compost is subjected to screening on a rotary sieve with mesh size of 20 mm in order to separate off-specification compost from stabilized compost.

The green waste composting plant also operates on the container-based system with KNEER containers. Its throughput is 13,000 Mg/year.

The landfill site (depot A) allows storage of stabilized compost originating from biological processing held at the MBP facility; the maximum amount of waste destined for disposal at depot A permissible under the integrated permit was 55,000 Mg in 2018, while the maximum amount will become lower in the following years – up to 1,500 Mg per year in the period of 2021-2030. Depot B of the landfill site is involved in disposal of slag and bottom ash from the ITPOK facility; the maximum amount of waste stored there under the issued permission is 40,562 Mg on an annual basis. The landfill site is facilitated with a leachate and biogas intake and removal system[94].

Incineration plant

The Municipal Waste Disposal Plant (Polish abbreviation: ZUOK) in Białystok is one of the first Polish facilities used for thermal conversion of municipal waste. Its construction commenced in December 2013 and it was commissioned on 1 January 2016. The incineration plant in Białystok receives waste from nearly 400,000 inhabitants of Białystok and nine neighboring communes that signed inter-municipal agreements with Białystok. The throughput of the Municipal Waste Disposal Plant in Białystok is 15.5 Mg/h, i.e. 120,000 Mg/year at heating value of municipal waste oscillating around 7.5-10.0 MJ/kg. The volume of processed municipal waste subjected to thermal processing at the ZUOK facility in Białystok becomes fifteen times lower, while its mass after incineration – three times lower.

The ZUOK facility in Białystok was constructed as a part of EU-funded project titled "The integrated municipal waste management system for the agglomeration of Białystok" which involved construction of three facilities, namely:

- a facility for thermal conversion of municipal waste with a capacity of 120,000 Mg/year,
- a facility for fixation and chemical stabilization (conversion facility) of ash and solid residuals from exhaust after-treatment with a capacity of approx. 8,600 Mg/year,
- a slag valorization plant with a capacity of approx. 36,500 Mg/year.

[94] Integrated permit issued under the decision of the Marshal of Podlaskie Voivodeship dated 26 April 2018 DOS-II.7222.2.1.2018.

The incineration plant in Białystok applied an exhaust after-treatment method based on the NID system, i.e. semi-dry technology combining several functions in one device: gas absorption of hydrogen chloride, hydrogen fluoride and sulfur dioxide; removal of heavy metals, dioxins, furans and particulates with the use of activated carbon and lime; and de-dusting of exhaust by using bag filters. Consequently, emission of pollutants in exhaust is minimized, with a value considerably lower than those provided for in the ordinance on emission standards from facilities[95]. Exhaust is under constant control conducted with an exhaust analyzer system.

The waste incineration plant operates in the cogeneration mode, i.e. the incinerated municipal waste is used in production of electricity and heating energy. The utilized technology allows annual production of approx. 43,000 MWh of electricity and around 360,000 GJ of heating energy, which is sent to the municipal heating network. The generated power resembles the amount of energy required to supply about 16,000 households and heating 875 single-family houses in Białystok during winter. A fraction of the energy generated through the operations of the plant is used for own purposes of the plant itself.

Since its launch, the incineration plant in Białystok constitutes a core element of the comprehensive municipal waste management system administered by LECH Sp. z o.o.

2.4. The municipal waste management system in Koszalin

General information

Koszalin is located in the north-eastern part of Zachodniopomorskie Voivodeship, being a municipality with district rights and the seat of authorities of the Koszalin District. It is the second largest city in West Pomerania. The city lies within the Koszalin Coast, on the Dzierżęcinka River and by Lake Jamno.

[95] The currently applicable Ordinance of the Minister of the Environment regarding emission standards for certain types of installations, sources of fuel combustion and equipment for incineration and co-incineration of waste was specified in the Notice of the Minister of the Environment dated 12 August 2019 on publication of the consolidated text of the Ordinance of the Minister of the Environment regarding emission standards for certain types of installations, sources of fuel combustion and equipment for incineration and co-incineration of waste, Polish Journal of Laws 2019 item 1806.

The city center is situated about 11 km from the Baltic Sea. The city spans over 98.32 km^2 while the population density is 1,095 people/km^2. According to the data of the Central Statistical Office, as of 31.12.2016, the city of Koszalin was actually inhabited by 107,680 persons[96].

The following system functions in Koszalin with regard to:

- mixed municipal waste – waste is accumulated within the property in containers featuring a capacity that reflects the needs of inhabitants; it is exported according to a set frequency. Export of mixed municipal waste from single-family houses takes place once a week, in the case of multi-family residential buildings – twice or three times a week;
- sorted municipal waste – in the case of multi-family residential buildings, there are so-called nests used for selective collection of waste, which comprise of containers for plastic, metals, composite and glass packaging, paper and cardboard. This type of waste is exported once a week; in some occasions – twice a week. Residents of single-family houses use bags or containers for sorted waste, i.e. plastic, metals, glass packaging, paper and cardboard; waste is exported once a week.

The city of Koszalin is divided into two sectors for collection of municipal waste (of similar size as to the area and number of served inhabitants). Services for collection and management of municipal waste in both sectors of Koszalin are rendered by Przedsiębiorstwo Gospodarki Komunalnej sp. z o.o. in Koszalin, which was awarded the procurement in an open tender.

Przedsiębiorstwo Gospodarki Komunalnej Sp. z o.o. in Koszalin

Przedsiębiorstwo Gospodarki Komunalnej (PGK in short) Sp. z o.o. in Koszalin is a company with long-term history and experience within the scope of waste management. During realization of statutory obligations concerning waste management, PGK, along with local authorities, inhabitants and companies of the Koszalin region, implemented a system of selective collection of municipal waste which adheres to the requirements provided for in Community, domestic and local regulations of law.

The company is one of the oldest municipal enterprises in Poland. It was established on 1 January 1949 as Zakład Oczyszczania Miasta (City Cleansing

[96] Central Statistical Office, *Ludność…*, op. cit.

Plant) which in 1954 became a part of Miejskie Przedsiębiorstwo Gospodarki Komunalnej Municipal (Waste Management Company), which was transformed into Przedsiębiorstwo Gospodarki Komunalnej (Communal Management Company) in 1975.

As part of activities in the scope of processing and managing municipal waste, PGK Sp. z o.o. in Koszalin launched in 2003 a Regional Waste Recovery Plant in Sianów (nearby a waste landfill site existing since 1978), which handles municipal waste recovery and disposal processes involving, i.a. sorting plastic and waste paper, recovery of secondary raw materials, composting green waste and other bio-waste, production of organic fertilizers, and storage of waste. The general profile of activities conducted by PGK Sp. z o.o. in Koszalin, according to its articles of association, comprises of: processing and removal of non-hazardous waste; collection of non-hazardous waste; cleaning, managing green zones, production of electricity, dismantling and demolition of building structures.

The Regional Waste Recovery Plant in Sianów, administered by PGK Sp. z o.o. in Koszalin, is the Regional Municipal Waste Facility for the Eastern Region of Municipal Waste Management[97]. The facility receives mixed waste collected within the area of the city of Koszalin. The rest of municipal waste collected selectively is partially deployed to the Plant in Sianów, while the remaining fraction is sent to other entities that hold relevant waste management permits.

It should be highlighted that PGK Sp. z o.o. in Koszalin conducts operations in the scope of collection and management of municipal waste generated outside Koszalin, namely in the following communes: Będzino, Bobolice, Malechowo, Polanów, Sianów, and Świeszyno.

Waste streams and their management

The amount of municipal waste collected as part of the municipal waste management system in Koszalin in the period of 2014-2017 has been presented in Table 17. The details do not cover waste handed over by inhabitants at selective collection points. The analysis of particulars in Table 17 shows that the highest amount of collected municipal waste is constituted by non-sorted,

[97] Resolution XVIII/321/16 of the Local Government Assembly of Zachodniopomorskie Voivodeship dated 27 December 2016 on adoption of the revision of the Municipal Waste Management Plan for Zachodniopomorskie Voivodeship for the period of 2016-2022 with the acknowledgment of prospects for the period of 2023-2028.

mixed municipal waste designated as 20 03 01. One may notice an inconsiderable increase in collection of mixed municipal waste within Koszalin. However, the percentage of such waste, compared to the stream of municipal waste mass in 2014, equaled 71.3%; in 2017, it decreased to 63.4%. The constant reduction of percentage of mixed waste in the stream of municipal waste results from the increased significance of selective collection of waste. What is more, the amount of municipal waste collected in Koszalin in the recent years has been steadily increasing by approx. 5%. It can be treated as evidence for further organization of the municipal waste management market in Koszalin. The waste accumulation waste in 2016 was relatively high, for Polish conditions, and equaled 449.1 kg/inhabitant/year.

Table 17. Amount of municipal waste collected in the city of Koszalin in the period of 2016-2017 [Mg]

Type of waste	2014	2015	2016	2017
Packaging waste (sub-group 15 01)	4,633.5	4,614.5	4,822.1	5020.8
Waste from construction, renovation and demolition of building structures (group 17)	4,282.7	5,672.8	6,269.2	6440.1
Used tires (16 01 03)	7.7	5.6	0.0	0.0
Unsorted municipal waste (20 03 01)	29,409.7	29,831.3	30,760.8	30,517.7
Biodegradable waste (kitchen waste, marketplace waste, etc.)	942.4	1057.3	2330.9	3863.6
Large-size waste (20 03 07)	667.5	495.4	338.1	760.3
Electrical and electronic waste	9.4	10.4	7.8	68.5
Raw material fraction of selectively collected municipal waste (paper, metals, plastic) (sub-group 20 01)	146	51.8	0.05	23.8
Other municipal waste (group 20)	1104.8	1333.306	1139.6	1421
Total	41,203.7	43,072.4	45,668.5	48,116

Source: own analysis based on the Analysis of the condition of municipal waste management system within the commune of the city of Koszalin in 2014-2017.

Table 18 reflects information on the mass of waste accepted at the point of selective collection of municipal waste (PSZOK) operating in the city. Additionally, in September 2014, an auxiliary selective collection point was established, the so-called site for selective collection of municipal waste (Polish

abbreviation: MSZOK); the details in the table also include the amount of waste collected at the MSZOK facility.

Table 18. Mass of waste accepted at PSZOK and MSZOK facilities in Koszalin in the period of 2014-2017 [Mg]

	2014	2015	2016	2017
PSZOK	1,103.4	1,242.3	2,093.1	2,249.5
MSZOK	39.4	484.7	600.3	696.1
Total	1,142.8	1,727.0	2,693.4	2,945.6

Source: own analysis based on the Analysis of the condition of waste management in the commune of the city of Koszalin in 2014-2017.

Table 19 has presented the level of recycling and the decrease in storage of biodegradable waste achieved by Koszalin. According to available data, in years 2014-2017, the commune achieved all the required levels of recycling, preparation to reuse, recovery with other methods, and limitation of the mass of biodegradable municipal waste deployed to the landfill site. Moreover, the level of recycling in the raw material fraction in 2017 presented a significant increase compared to 2016.

Table 19. Levels of recycling and preparation to reuse of waste and levels of reduction in biodegradable waste deployed for storage within years 2014-2017 achieved in the commune of the city of Koszalin

Specification	2014	2015	2016	2017
Level of recycling of raw material waste [%]	23.82 [min. 14]	24.01 [min. 16]	22.41 [min. 18]	31.03 [min. 20]
Level of recycling of construction and demolition waste [%]	90.58 [min. 38]	74.61 [min. 40]	76.09 [min. 42]	67.02 [min. 45]
Level of amount of biodegradable waste sent to be stored [%]	11.30 [max. 50]	20.56 [max. 50]	0 [max. 45]	0.08 [max. 45]

Source: Analysis of the condition of municipal waste management within the commune of the city of Koszalin in 2014-2017.

The fee for management of municipal waste

As part of the municipal waste management system in Koszalin, the commune collects municipal waste from inhabited and partially inhabited real properties (which, apart from apartments, include business premises), while their owners pay a fee for the service. In the case of partially inhabited real

properties, the fee is a total of the rate for the residential area (calculated according to the price list) and the rate for business premises based on the unit rate and floor area of the premises. Owners of uninhabited real properties are obligated to conclude independent agreements for collection of waste. Rates of fees applicable since the beginning of 2016 have been specified in Table 20.

Table 20. Rates of applicable fees for waste management in Koszalin

Residential premises with a floor area falling within [m²]:	Waste accumulated selectively [PLN]	Waste accumulated non-selectively [PLN]
0 to 25	13.5	20.3
25.01 to 30	18.5	28.0
30.01 to 40	23.5	35.3
40.01 to 50	28.5	42.8
50.01 to 70	33.5	50.3
70.01 to 90	39.0	58.5
90.01 to 120	44.0	66.0
120.01 to 150	50.0	75.0
over 150.01	55.00	82.5
Floor area of residential premises	0.60 PLN/m²	0.90 PLN/m²

Source: Resolution no. XV/181/2015 of the City Council of Koszalin dated 26 November 2015 on selection of the method for determination of the fee for municipal waste management and determination of the rate of such fee, Official Journal of Zachodniopomorskie Voivodeship dated 4.12.2015, item 5066.

Regional Waste Recovery Plant in Sianów

The Regional Waste Recovery Plant (Polish abbreviation: RZOO) in Sianów, administered by PGK Sp. z o.o. in Koszalin, is a regional facility for processing of municipal waste in the eastern region of Zachodniopomorskie Voivodeship – is is a waste management facility which ensures mechanical and biological processing of mixed municipal waste and the possibility of extracting fractions that can be fully or partially recovered from mixed municipal waste. The RZOO facility in Sianów receives mixed communal waste accumulated within the city of Koszalin. According to the waste management plan for Zachodniopomorskie Voivodeship, the MBP facility in Sianów features an annual capacity of 75,000 Mg, in terms of mechanical processing, and 65,000 Mg, with regard to biological processing.

The facility consists of two core segments:

- a facility for mechanical processing of municipal waste – equipped mainly in a sieve with a 80 mm mesh, as well as a ballistic separator, 2D and 3D separators (for, respectively, extraction of flat and rolling fractions), as well as manual sorting lines. The process of separation involves the following fractions: paper, cardboard, foil, white PET, colored PET, PE/PP, Tetra Pak, ferrous and non-ferrous scrap, and pre-RDF;
- a facility for biological processing of fractions of biodegradable waste separated through mechanical processing of mixed municipal waste – it functions on the basis of closed aerobic composting which is based on the GORE membrane technology. The facility is to perform aerobic stabilization in protected conditions until obtaining biodegradable contents in the said fraction at the required level of AT4 < 20 mgO_2/g of dry mass. Next, the fraction is subjected to further aerobic stabilization in 10 piles enclosed in a semi-permeable membrane that protects the stabilized material from being penetrated by precipitation and, at the same time, from loss of process heat and emission of aerobic bacteria and process odors – such a process is conducted until achieving the required level of AT4 < 10 mgO2/g of dry mass. When the desired level is acquired, the biodegradable fraction can be stored at the landfill site (as the so-called stabilized compost).

Diagram 6 has illustrated the flow of unsorted mixed municipal waste conducted at the RZOO facility in Sianów.

As part of the RZOO facility, there is also a composting plant for green waste and other bio-waste, which operates independently from the MBP facility, with the status of a regional facility (so-called green RIPOK facility). The annual capacity of the said facility, according to the waste management plant for Zachodniopomorskie Voivodeship, is 30,000 Mg.

Moreover, the RZOO facility also includes a landfill site for hazardous and neutral waste, which allows storage of waste generated in the mechanical and biological processing of mixed municipal waste and storage of sorting residues from municipal waste.

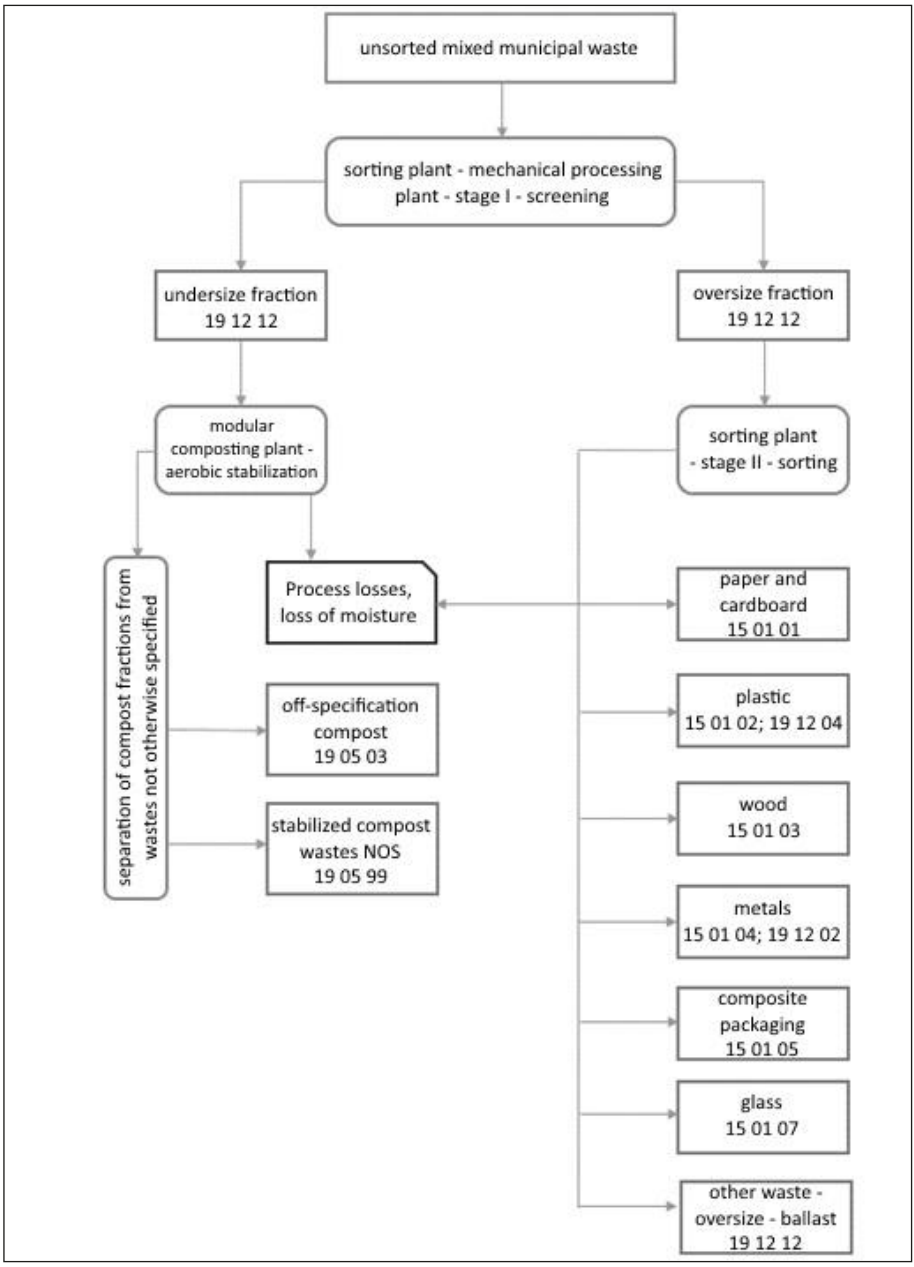

Diagram 6. The diagram of flow of unsorted mixed municipal waste through the RZOO facility in Sianów

Source: own analysis.

2.5. Municipal waste management in Nowy Targ

The city of Nowy Targ (a municipal commune) lies in Małopolskie Voivodeship and it is the seat of authorities of the district of Nowy Targ. The city spans over an area of 51.07 km^2. As of 31.12.2016, the number of permanent or temporary inhabitants was 32,453.

The organization and supervision over the municipal waste management system is conducted by the City Hall of Nowy Targ (among others, through operations of the Department of Municipal Management and Environmental Protection and the Tax and Charges Department). The system covers 26,003 persons. In the case of single-family residential premises, 4,638 statements have been filed; in the case of multi-family residential premises – 141. The discrepancies in the numbers of permanent inhabitants named in filed statements result, among others, from the fact that many students study and live outside their permanent place of residence and that people migrate from Nowy Targ for occupational reasons, despite their domicile. Moreover, the system covered 921 uninhabited real properties (in 2016).

As a result of an open tender held from 1 January 2015 to 31 December 2017, collection and management of municipal waste from real property owners in Nowy Targ is conducted by the consortium of companies P.U.K. "Empol" Sp. z o.o. and IB Sp. z o.o.

In 2016, collection of municipal waste from inhabited and uninhabited real properties was performed as follows:

- selectively, where the following fractions are separated:
  - dry fraction (paper, metal, plastic, composite packaging and beverage and food bottles and jars, alcoholic beverage bottles, glass cosmetic packaging separated and accumulated in bags marked as "Glass"),
  - wet fraction includes other mixed municipal waste,
  - ash/bio-waste covers, interchangeably, ash or bio-waste, namely biodegradable waste from green zones, food and kitchen waste, as well as waste of similar character and composition, accumulated in bags marked as "Bio-waste",
- non-selectively, with the following fractions separated:
  - mixed fraction (dry, wet),

– ash/bio-waste covers, interchangeably, ash or bio-waste, namely biodegradable waste from green zones, food and kitchen waste, as well as waste of similar character and composition, accumulated in bags marked as "Bio-waste".

Within the commune of city of Nowy Targ, the steam of municipal waste is also divided into: used electrical and electronic equipment, used batteries and rechargeable batteries, furniture and other large-size waste, drugs past their expiry date and chemicals, construction and demolition waste, and used tires.

The point for selective collection of municipal waste is located at the MBP facility in Nowy Targ, which is the property of the company IB Odpady Sp. z o.o. What is more, there are also the so-called mini-points for selective collection of municipal waste (nest system), to which inhabitants can deliver waste sorted into fractions: paper, metal, packaging plastic and glass (2 points) or packaging plastic and glass (33 points).

Rates of fees for municipal waste management were determined in 2016 by way of resolution of the City Council of Nowy Targ and they equal[98]:

- for owners of inhabited single-family properties:
  – PLN 8.50 per person/month (selective system) or
  – PLN 15.00 per person/month (non-selective system).
- for owners of inhabited multi-family real properties:
  – PLN 9.50 per person/month (selective system) or
  – PLN 15.00 per person/month (non-selective system).

In the case of uninhabited real properties, the fee is charged per number of waste bins, whereby it is differentiated depending on the fact whether the waste is accumulated selectively or non-selectively.

The amounts regarding municipal waste collected in Nowy Targ in years 2016-2017 have been compared in Table 21. In 2016, the waste accumulation rate (calculated based on the population stated by the Central Statistical Office) amounted 329 kg/inhabitant/year.

[98] Resolution no. XXV/211/2016 dated 27.06.2016 of the City Council of Nowy Targ on selection of the method for determination of the fee for municipal waste management and determination of the rate of such fee, Official Jounrla of Małopolskie Voivodeship dated 6.07.2016 item 4023.

Table 21. Amount of municipal waste collected in the commune of city of Nowy Targ in 2016-2017 [Mg]

Fraction	2016	2017
Dry	472.94	524.20
Wet + Mixed	7,421.20	7,661.13
Bio-waste	994.04	1,135.86
Ash	1,171.84	1,177.98
Glass	25.06	92.88
Furniture and large-size waste	449.67	659.12
Construction and demolition waste	146.32	177.58
Used tires	2.12	3.18
Electrical and electronic equipment	2.58	8.04
Drugs past their expiry date	1.43	1.06
Chemicals	0.58	0.12
Total	10,687.78	11,441.18

Source: Analysis of the condition of municipal waste management within the commune of city of Nowy Targ in 2017.

The consortium of companies rendering services of collection and management of municipal waste, under an agreement with the commune of the city of Nowy Targ, deployed waste to two facilities owned by private companies. The said facilities are:

- Zakład Zagospodarowana Odpadów Tylmanowa, exploited by PUK "Empol" Sp. z o.o., with the following capacity:
  - processing of mixed municipal waste – 65,000 Mg/year (mechanical section) and 30,000 Mg/year (biological section),
  - a facility for biological processing of green waste – 1,200 Mg/year.
- IB Zakład Utylizacji Odpadów Nowy Targ, exploited by IB Odpady Sp. z o.o., with the following capacity:
  - processing of mixed municipal waste covering the mechanical section – 27,500 Mg/year,
  - a facility for biological processing of biodegradable waste – 11,000 Mg/year, with the possibility of sorting selectively collected waste up to 42,500 Mg/year,

– generation of combustible waste (alternative fuel) – up to 100,000 Mg/year.

The said facilities, which constitute the private property of entities from the waste management market, accept municipal waste not only from the city of Nowy Targ, but also from other communes.

The levels of recycling and reduction in amount of biodegradable waste deployed for storage achieved in Nowy Targ have been presented in Table 22. One may notice the considerable increase in the level of recycling and preparation to reuse of the raw material fraction – in 2017, a level of nearly 60% was achieved. In Nowy Targ, similarly to other analyzed Polish cities, the amount of biodegradable waste deployed for storage is negligible (7.7% in 2017) or at zero level (in 2016).

Table 22. Levels of recycling and preparation to reuse of waste and levels of reduction in biodegradable waste deployed for storage within years 2016-2017 achieved in the commune of the city of Nowy Targ

Specification	2016	2017
Level of recycling of raw material waste [%]	19.90 [min. 18]	59.90 [min. 20]
Level of recycling of construction and demolition waste [%]	100 [min. 42]	59.40 [min. 45]
Level of amount of biodegradable waste sent to be stored [%]	0 [max. 45]	7.7 [max. 45]

Source: Analysis of the condition of municipal waste management within the commune of city of Nowy Targ in 2017, 2018.

Summing up, the presented examples of municipal waste functioning in four Polish cities allow formulating several key technical and organizational findings specific for management of municipal waste. Cracow and Białystok exemplify cities with comprehensive municipal waste management systems that feature closed circulation (accumulation, processing, recycling, recovery, incineration, and storage). Both cities are characterized by a self-governmental model of municipal waste management, whereby Cracow tradition spans over 150 years and it utilizes the best and historic organizational and technological experience. For instance, the construction of the advanced Barycz landfill site took place before Poland joined the EU while using pre-accession funds of the ISPA. In the case of Cracow, the commune entrusted administration of the municipal

waste management system to a company that transferred its former exploitation functions (collection and transport of waste) to a subsidiary established in 2013. Białystok serves as an example of a city, where the commune founded a new company to administer the developed municipal waste management system.

In Koszalin, municipal waste management is organized by the local self-government but – as it has been discussed – it struggles with technical and organizational limitations, e.g. lack of an incineration plant. In spite of such limitations, the self-government of Koszalin ensures fulfillment of general technical and organizational standards of municipal waste management in the city. The commune needs further development of the urban management system for municipal waste.

Municipal waste management in Nowy Targ most certainly reflects different characteristics. Here, the dominant is constituted by private facilities focused on commercial services provided not only for their own commune, but for neighboring communes as well. From the perspective of commercial companies, eventual optimization refers rather to individual facilities, not the system as a whole, to achieve high financial results.

Based on the presented examples, one may, with a dose of caution, conclude that the self-governmental model of organization of a municipal waste management system has the advantage of ensuring technical and organizational standards of municipal waste management in cities. In terms of the extent of ensured economic advantages (economic and financial effectiveness), an attempted evaluation has been made in Chapter 4. Before that, however, examples have been provided for the organization of municipal waste management systems in selected foreign cities (Chapter 3). It must be added that both Polish and European cities (discussed in Chapter 3) are subject to EU regulations and standards on municipal waste management system.

Chapter 3.

MUNICIPAL WASTE MANAGEMENT IN SELECTED EUROPEAN CITIES

3.1. Management of waste in selected cities of the Federal Republic of Germany

This section has been devoted to the analysis of the methods of municipal waste management used in cities of several EU member states. The overview of functioning of municipal waste management systems has been conducted for both the so-called old EU states as well as the new ones: Germany, Austria, and the Czech Republic. The waste management method in Germany has been presented with the acknowledgment of differences between the so-called old and new federal states – lands.

Waste management within the territory of the Federal Republic of Germany is subject to regulations of the general legal act which governs the aspects of both the marketing of packaging waste and municipal waste as well as other types of waste, with minor exceptions: Gesetz zur Förderung der Kreislaufwirtschaft und Sicherung der umweltverträglichen Bewirtschaftung von Abfällen (the act on aiding management in closed circulation and ensuring waste management compliant with environmental requirements). The act was adopted by the Bundestag on 27 September 1994 and entered into force on 1 January 1996. Currently, the act has been functioning based on its revision dated 24 February 2012. The shortened name of the act – Kreislaufwirtschaftsgesetz – the act on management in closed circulation (KrWG) is commonly accepted.

The act on management in closed circulation:

- regulates issues connected with removal of waste,
- introduces a waste handling hierarchy,
- introduces the obligation of selective accumulation of waste, its selective collection and further sorting,
- introduces the principle of ultimate disposal of other waste after material extraction, particularly through thermal processing; as the goal of ultimate disposal, it specifies liquidation of hazardous (mainly organic) substances.

The act on closed circulation covers all waste processing facilities other than landfill sites. Waste landfill sites were excluded from provision of the act due to the significant environmental threat posed by landfill sites; they have been subjected to regulations of the federal act on protection against immission (BImSchG).

The act on management in closed circulation governs the following aspects:

- rights and obligations of the producer of waste, waste holder, public law obligations,
- product liability,
- waste management planning, liability for plan preparation,
- promotion of proper waste management, consultancy regarding waste management,
- supervision over waste management,
- waste processing facilities,
- organization of waste management and responsible authorities.

Apart from waste landfill sites, regulations of the act on management in closed circulation also do not refer to:

- management of radioactive waste,
- disposal of carcasses and slaughterhouse waste,
- mining waste,
- gas waste not accumulated in containers,
- substances discharged to rivers (receivers) in treated sewage,
- used ammunition and other warfare agents.

The act on management in closed circulation governs two crucial issues within the scope of waste management – it specifies the authority responsible for waste management and the method such waste is managed with.

The circumstances of organizational character, which occur at the German market of municipal waste management are similar to those present in Poland. In general, there is a distinction between services concerning collection of municipal waste and services regarding its management. The market of waste management in the Federal Republic of Germany is characterized by a constant improvement of the efficiency of systems for selective accumulation of waste, which leads to a decrease in the size of stream of unsorted waste. A significant contribution to the process of minimization of the stream of unsorted waste is also provided by the implemented domestic preventive program on generation of waste, which shapes relevant behavior among consumers.

Matters concerning selective collection of waste have been developed on the German market since 1985 – the date of introduction of selective collection for bio-waste. In 1991, the mandatory selective collection of packaging waste was introduced.

Currently (as of 2018), the Federal Republic of Germany generates about 14 million Mg of unsorted mixed municipal waste on a yearly basis; according to forecasts, the said amount will decrease by another 1 million Mg by 2020. For comparison, the amount of non-sorted waste generated in Germany in 2000 equaled approx. 15 million Mg. Observations also reveal that within the last 15 years there has been a minor, yet continuous increase in the amount of collected biodegradable waste, light fraction packaging waste, and paper. It indicates a growing efficiency of the implemented systems for selective accumulation of waste. The amount of generated glass waste and large-size waste shows a declining trend. In the case of glass, one may notice the influence of replacement of glass packaging with light types (plastic, Tetra Pak, aluminum); in the case of large-size waste - the implemented national plan for prevention of generation of waste has brought positive results. Currently, the amount of all generated municipal waste (with the acknowledgment of the so-called municipal-like waste) equals around 50 million Mg a year. It means that a more significant part of the stream of waste is collected in the selective manner. Changes in the stream of municipal waste in the period from 2000 to 2016 have been presented in Chart 4.

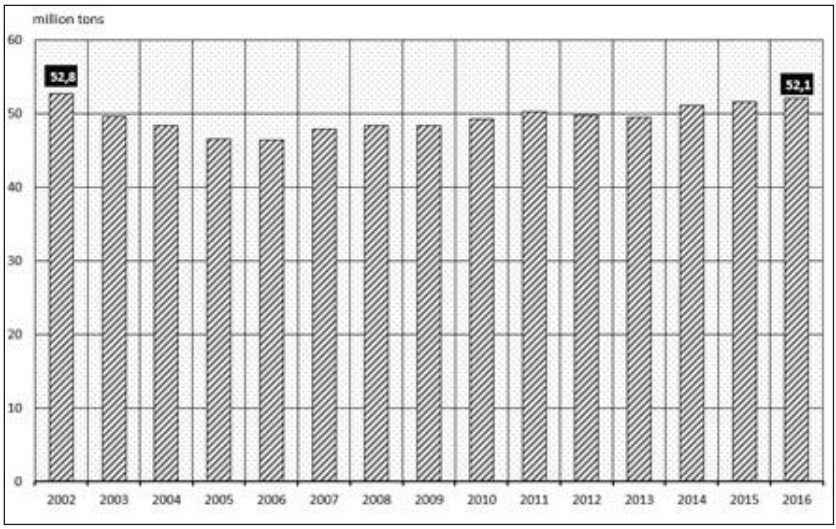

Chart 4. Changes in the total stream of municipal waste in Germany, period of 2002-2016

Source: own analysis based on data from the Federal Statistical Office, Abfallbilanz 2016, Wiesbaden 2018.

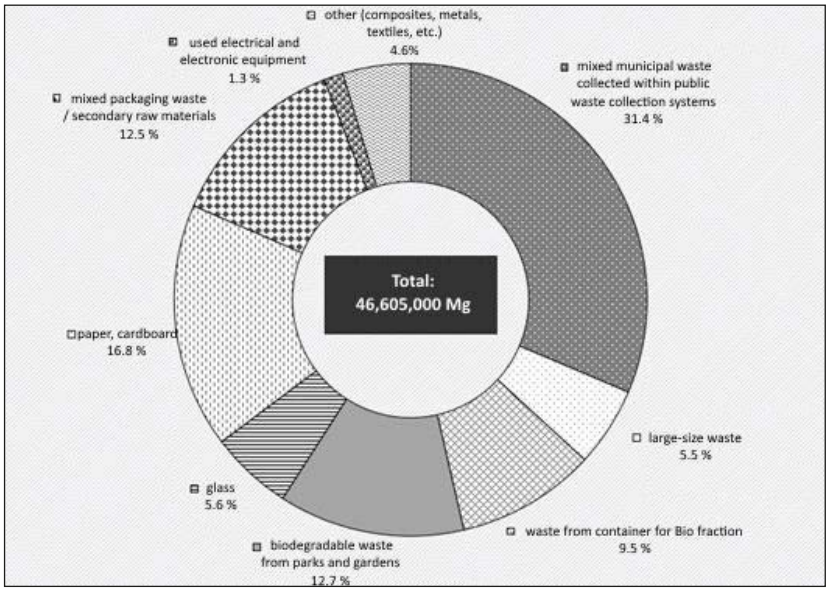

Chart 5. Percentage of individual fractions of typical municipal waste collected selectively in Germany in 2016

Source: own analysis based on data from the Federal Statistical Office, op. cit.

In 2016, the amount of municipal waste collected from households through public systems of collection of municipal waste in Germany amounted 46.6 million Mg. The component fractions of such waste have been specified in Chart 5.

The attention should be drawn to the percentage of municipal waste processed and subjected to recycling in the total amount of municipal waste generated in Germany. Chart 6 has illustrated the development of amount of waste that was processed/subjected to recovery and recycling in Germany compared to goals set for 2020.

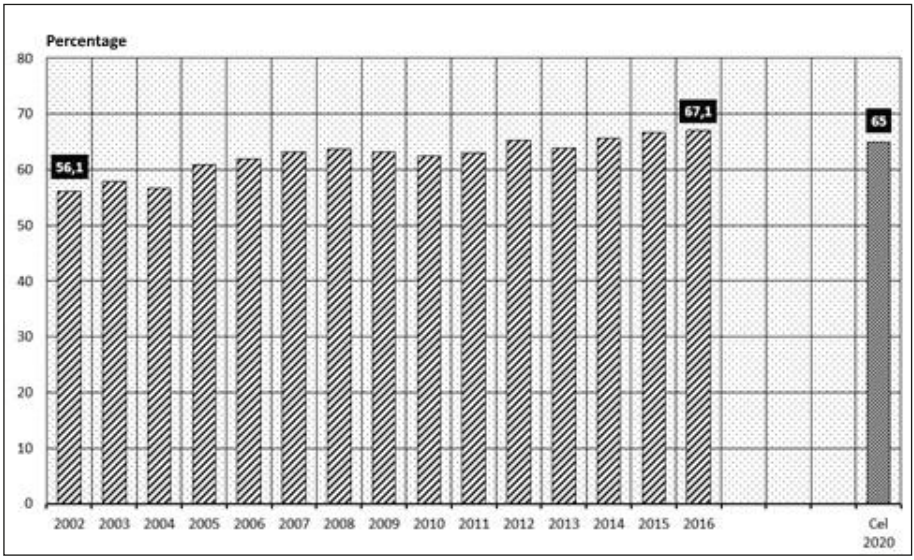

Chart 6. Change in the percentage of municipal waste processed and subjected to recycling in Germany in the total amount of municipal waste, 2002-2016

Source: own analysis based on data from the Federal Statistical Office, op. cit.

The amount of waste (excluding used electrical equipment) generated yearly by one German inhabitant is 462 kg (Chart 7).

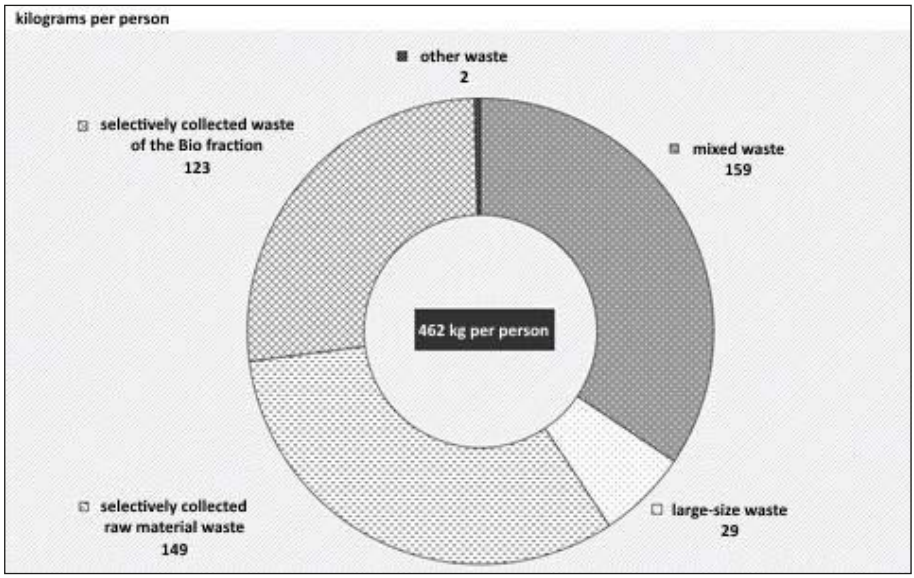

Chart 7. Indicators of accumulation of individual fractions of municipal waste per 1 person in Germany in 2016.

Source: own analysis based on data from the Federal Statistical Office, op. cit.

Management of municipal waste in selected cities of the Federal Republic of Germany

This dissertation has provided an analysis of the method of managing municipal waste in two German cities: Frankfurt am Main, which represents the "old" federal states, and Frankfurt an der Oder, which is located in the territory of the former German Democratic Republic. The general details regarding the discussed cities have been listed in Table 23.

Table 23. General data characterizing the analyzed cities in the Federal Republic of Germany

City	Frankfurt am Main	Frankfurt an der Oder
Population	736,414	58,092
Area	248.31 km^2	147.85 km^2
Population density	3026.6 people/km^2	392.9 people/km^2
Federal state	Hessen	Brandenburg

Source: own analysis.

Municipal waste management in Frakfurt am Main

The system of collecting waste from real property owners in Frankfurt am Main (Diagram 7) reflects a typical system similar to those functioning generally all over the Federal Republic of Germany. The function of administration over the municipal waste management system in the city is performed by the Environmental Office (Umweltamt) that constitutes a part of the structure of the Frankfurt city hall. Waste management in Frankfurt am Main involves the company FES Frankfurter Entsorgungs- und Service GmbH which is a limited liability company with a share capital of EUR 4,100,000.00; 51% of the company is owned by the city of Frankfurt am Main, 49% belongs to the company Remondis AG&Co. KG.

Collection and accumulation of waste

Frankfurt am Main runs a system for collection of solid waste from real property owners; it is divided into the following fractions:

- Collection organized by the commune:
  - household (mixed) waste, collected from black or gray containers standing within the real properties,
  - biodegradable waste, collected from brown containers standing within the real properties,
  - paper and cardboard waste, collected from blue containers standing within the real properties,
  - large-size waste, collected on certain dates through "curbside recycling",
  - electrical and electronic scrap, collected on certain dates through "curbside recycling" or delivered to a point for selective collection of municipal waste,
  - points for selective collection of waste,
  - hazardous waste, mobile collection, 2 x a year or delivered to a point for selective collection of municipal waste;
- Collection through recovery organization:
  - light packaging fraction, collected from yellow containers standing within real properties,
  - light packaging, collected from sorting stations,
  - packaging glass, collected from sorting stations.

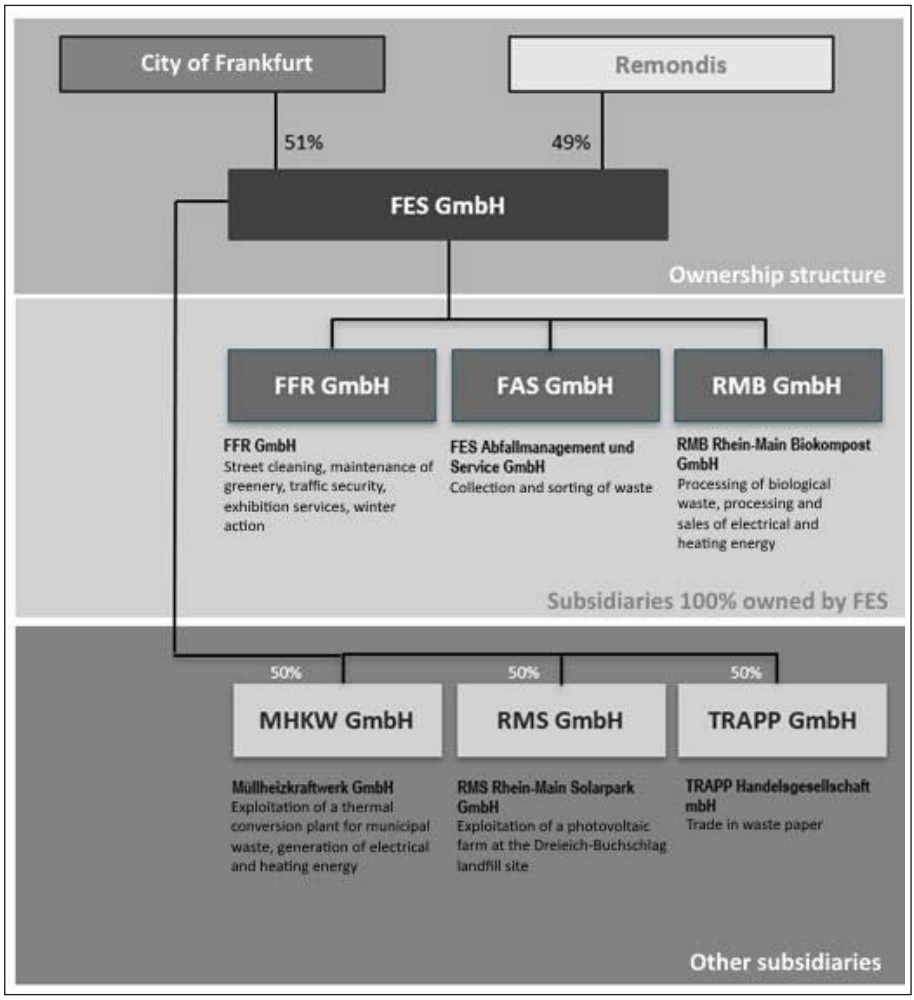

Diagram 7. The organizational structure of companies liable for management of municipal waste in Frankfurt am Main

Source: own analysis based on data from FES.

Management of waste

The implementation of actions connected with management of waste is conducted at facilities which are directly or indirectly administered by FES. FES manages its own municipal waste processing facilities and – through subsidiaries – third-party facilities.

FES manages the following waste processing facilities it owns:

1) **A waste loading terminal** located in the Frankfurt Eastern Shipyard. The terminal serves a logistics role connected with optimization and deploying streams of waste to individual facilities used for processing, management and disposal of municipal waste which operate by using various technologies. The terminal is used for loading of large-size waste, wood, plastic, and construction waste. It helps in reducing the number of journeys required for vehicles used to transport waste. The terminal is also used to load mixed waste.
2) **Waste paper sorting plant**, located in a hall of floor space of 4,000 m^2, at Ferdinand Porsche Straße in Frankfurt. At the facility, waste paper is sorted by assortment and grain size; mixed low-quality paper is also separated.
3) **Hazardous waste storage facility**. The hazardous waste storage facility is used for temporary accumulation of various chemical substances until the stored amount allows economically justified transport of such waste. The storage facility, owned by FES, stores hazardous waste originating both from households and from businesses. The accumulation includes flammable, explosive, toxic, and corrosive waste. They are collected in a selective manner, in relevant containers that ensure safe storage. The storage facility has a fire and anti-theft surveillance system. The whole hall is facilitated with a double-structured floor that also serves as a "collector basin" in case of any leakage of the stored substances.
4) **Slag management facility**. Thermal conversion of waste generates by-products in form of ash and slag. The amount of slag, in terms of mass, equals about ¼ of the amount of municipal waste subjected to thermal conversion. Slag also contains unburnt fractions of municipal waste like metals, glass, inert materials, ceramics. The main purpose of the slag management facility is: to separate the fraction of ferrous and non-ferrous metals from slag to deploy them to be reused; to screen the remaining slag into fractions by grain size; and to make maximum use of slag, mainly for landfill site covers and roads. The facility processes slag from five incineration plants in: Frankfurt, Mainz, Offenbach, Darmstadt and Mannheim.

FES is also a shareholder in specialist companies established for the purpose of managing waste processing facilities. Among plants managed by those companies, one should distinguish:

1) **Thermal municipal waste conversion plant**. The thermal municipal waste conversion plant (the literal translation of the German name is waste-powered heat and power generating plant) located in Frankfurt, at Heddernheimer Landstraße 157, is administered by a subsidiary MHKW Müllheizkraftwerk Frankfurt am Main GmbH, 50% of which is owned by FES GmbH and the remaining 50% – by heat generating company Mainova, 75.2% of which is indirectly held by the city of Frankfurt. The share capital of the company amounts EUR 25,000. The thermal municipal waste processing plant itself is the property of Mainova, a company responsible for generation and supply of heat energy in Frankfurt. 75.2% of the joint-stock company Mainova belongs to Stadwerke Frankfurt am Main Holding (100% owned by the city), 24.5% – to Thüga AG (Thüringer Gas AG – 100% subsidiary of Thüga Holding – a company being a part of the consortium of Integra/Kom9 self-governmental enterprises). The remaining 0.3% shares of Mainova is formed by scattered shareholding. The thermal municipal waste conversion plant in Frankfurt am Main is one of the largest facilities of this kind in the Federal Republic of Germany. The annual throughput of the facility equals 525,600 Mg; on an annual basis, it generates 1.5 million Mg of steam. The stream of waste at the facility is reduced by about 88%, the mass – by around 75%. The incineration plant was built in mid 1960s. At the beginning of its operations, the generated steam would be deployed to the neighboring heat and power plant. In the period of 1984-87, the facility was modernized and adjusted to the changed technological demands. In 2005, the plant was once again reconstructed due to the necessity of adhering the waste processing system to stricter regulations, particularly to the adopted ban on storage of mixed municipal waste that has not been processed with thermal or biological manner. At the same time, the city of Frankfurt and Mainova AG decided to mutually administer the facility. In 2006, the company MHKW was founded in order to manage the incineration plant.
2) **Facility for biological conversion of biodegradable waste**. The facility for biological conversion of biodegradable waste is managed by RMB Rhein-Main Biokompost GmbH, a subsidiary owned in 100% by FES GmbH. The plant is used for processing of biodegradable waste with combined methods: with the use of anaerobic fermentation and standard composting. The process of anaerobic fermentation produces biogas in form

of methane. Biogas is combusted in methane-fueled engines at the in-house block heat and power plant, in combination. Consequently, the heat and power plant generates both heat energy and electricity. The application of the anaerobic fermentation technology allows achieving a significant reduction in greenhouse gas emissions. The facility for anaerobic fermentation processes biodegradable waste accumulated in brown containers. In order to optimize the fermentation process, waste is mixed with other components, such as, for instance, animal feces. Electricity recovered at the facility is sold to the energy infrastructure as green energy. The composting process produces high-quality compost, which is used in plant production as humus agent that enriches the soil. In terms of CO_2 emission, composting is a neutral process. RMB holds certificates that allow using the compost as an enrichment agent, separately for fine compost and structural compost. The composting processes involves green waste and solid residue remaining after the process of anaerobic fermentation.

Fees for management of municipal waste

The fees in Frankfurt am Main for management of municipal waste are incurred by real property owners and they cover the costs of waste management in the city. Collection of fees is conducted by the city hall of Frankfurt. All the aspects connected with municipal waste collecting are attributable to the commune. The rate of the fee for management of municipal waste in Frankfurt am Main has been stipulated in the terms and conditions of payment of fees for waste management (Abfallgebührensatzung – AbfGS) dated 2 July 2004, amended on 16 November 2017.

The terms and conditions provide for payment duties and also specify the entities obligated to pay the fees. In Frankfurt, the use of municipal infrastructure within the scope of municipal management is subject to a fee. There is a mandatory flat rate fee for access to the infrastructure and a fee for rendered services connected with waste management. The fees cover the costs of:

- regular collection of residual and biodegradable waste,
- collection of waste paper as part of the "deliver" and "collect" systems,
- "car trunk" delivery of municipal waste to a point for selective collection of municipal waste,
- consultancy regarding waste,

- collection of small amounts of hazardous waste and batteries.

The flat rate fee is charged for every so-called using entity that utilizes a container through the replacement system, emptied container, or disposable waste packaging (bag). The fee is paid in advance for the whole year. According to the terms and conditions, it is assumed that a "using entity" stands for any of the following elements located within the real property:

- a household,
- or any other structure that utilizes the urban infrastructure, such as stores, workshops, or other business entities with a floor space of up to, and including, 200 m^2 of office space.

Every new further space of 200 m^2 of the office area is charged with another flat rate fee. At least one flat rate fee must be paid for each real property.

Apart from the flat rate fee, it is also mandatory to pay a service fee. The said fee applies to every emptied container, replaceable container, or disposable packaging for waste made available to the using entity. The service fee is charged for emptying containers with mixed waste and it also acknowledges the cost of collecting waste from other containers handled as part of the municipal system (bio-waste and paper). If the waste exporting company decides that the container for other types of waste (e.g. secondary raw materials or bio-waste) contains over 10% of mixed waste, the emptying of the container is charged with an additional fee for emptying a container with mixed waste.

When the emptied container has to be moved from the backyard to the garbage truck and the distance exceed 15 m, an additional transport fee is charged.

The fees for municipal waste management in Frankfurt have been determined at the following level (selection of rates illustrating the costs):

1) the flat rate fee: €66.00 per year;
2) the service fee – use of waste containers which are emptied on a regular basis, charged for weekly emptying (listed fees are for several selected size options for containers): 80 l - €14.10; 120 l - €21.15; 240 l - €42.31; 770 l - €135.75, 1100 l - €193.93. If the container or the bin is emptied more often than once a week, the fee becomes proportionally higher. A fee was also determined for each occasional emptying that would be additional to the set schedule of waste removal; such a fee, respectively for the examples of a/m containers, amount: €3.25, €4.88, €9.76, €31.33, €44.75. Users of house composters are entitled to a discount for waste management for the part charged

for rendered services. The discount equals from €7.92 (in case of an 80 l container) to € 108 (for a 1,100 l container). An additional fee of € 3.00 is charged for access to a 70 l waste bag. The act has also introduced a fee for the customer's delivery of waste for processing. In the case of unsorted mixed municipal waste designated as 20 03 01 the fee equals 213.00 €/Mg.

Municipal waste management in Frakfurt an der Oder

The affairs connected with maintenance of cleanliness in Frankfurt an der Oder are subordinated, in terms of supervision, to the Office of Roads, Ground Construction, and Urban Greenery (Amt 66 – Amt für Tief-, Straßenbau und Grünflächen). The office employs 5 persons for handling matters concerning management of municipal waste. The organization of the market of municipal waste management and maintenance of cleanliness is ensured by Frankfurter Dienstleistungsholding GmbH, a holding company 100% of which is owned by the city. In the holding company, matters regarding waste are delegated to 2 persons; moreover, inter-department in-house services involve a group of around 30 people (mutual accounting, legal department, marketing, customer service, etc.). Within the scope of waste management, the subject of operations of the company, according to provisions of the agreement, includes "removal of solid waste along with provision of services concerning waste management and expansion of the infrastructure used for waste management". However, the operational issues related to management of solid waste are dealt by the holding company within a limited scope that only involves preliminary processing of municipal waste. Other operations are entrusted to third-parties.

Frankfurter Dienstleistungsholding GmbH is liable for organizing the market of municipal waste management in Frankfurt an der Oder as the so-called third-party to whom the city entrusted the implementation of its own tasks. It should be highlighted that Frankfurt an der Oder entrusted the said holding company with implementation of all communal duties concerning municipal management, including, among others: public transport, heat supply, and gas supply. The entrustment was concluded without a tender for performance of such operations, based on the in-house principle, in accordance with Community, federal, and domestic law and the case law of the European Court of Justice. As part of implementation of its duties as a municipal commune, Frankfurt an der Oder coordinates tasks

connected with management of waste in the following scope: collection of waste from real property owners, loading, logistics and disposal, whereby it independently realizes duties within the scope of preliminary processing of waste.

Collection of municipal waste

The operations within the scope of collection of municipal waste in Frankfurt an der Oder, upon order of Frankfurter Dienstleistungsholding GmbH which administers municipal waste management, are conducted by entities selected through public procurement: Veolia and Becker+Armbrust.

Frankfurt an der Oder runs a system for collection of solid waste from real property owners; it is divided into the following fractions:

Collection organized by the commune:

- Household (mixed) waste, collected from containers standing within the real properties, with the use of weighing equipment installed on vehicles:
  - biodegradable waste, collected from containers standing within the real properties, with the use of weighing equipment installed on vehicles; in the case of such waste, a standard container volume of 15/l per inhabitant is assumed,
  - large-size waste, collected upon notification made based on a so-called yellow card,
  - electrical and electronic scrap, collected upon notification made based on a so-called yellow card.
  - paper and cardboard waste, collected from containers standing within the real properties,
  - points for selective collection of waste,
  - hazardous waste, mobile collection, twice a year;
- Collection organized by Duales System Deutschland (an equivalent of a recovery organization, a company functioning within the territory of the whole Federal Republic of Germany):
  - light packaging, collected from sorting stations,
  - packaging glass, collected from sorting stations.

The area of the municipal commune of Frankfurt an der Oder has not been divided into sectors of waste collection. Activities related to collection of municipal waste from real property owners, for whom the organizer is, on

behalf of the municipal commune of Frankfurt an der Oder, the company Frankfurter Dienstleistungsholding GmbH, is conducted by the general partnership Frankfurter Entsorgungsgesellschaft GbR that binds the consortium of companies Veolia and Becker+Armbrust, selected through tendering proceedings for the concession for collection of municipal waste and for partnership with FAW for the time of the service (namely 20 years). Efforts connected with collection of packaging waste, within the scope of light packaging and glass packaging, organized by the recovering organization, is conducted by a company selected through tender proceedings announced by the recovering organization – Duales System Deutschland. Nowadays, the said operations have been run by the company Veolia. The amount of collected municipal waste is approx. 20,000 Mg a year.

Processing of municipal waste

Preliminary processing of waste collected from real property owners is handled at the plant of FAW Frankfurter Abfallwirtschaft GmbH, a subsidiary of Frankfurter Dienstleistungsholding. Activities concerning pre-processing of waste from real property owners, organized on behalf of the municipal commune of Frankfurt an der Oder by the company Frankfurter Dienstleistungsholding GmbH, are conducted on a non-tender basis, under an in-house order awarded to FAW Frankfurter Abfallwirtschaft GmbH. The company is a non-profit establishment that holds strategic shares in the general partnership Frankfurter Entsorgungsgesellschaft GbR binding the consortium of Veolia and Becker+Armbrust, chosen as part of concession proceedings to be a partner of FAW throughout the period services are rendered for (20 years). The holding owns 52% in FAW; the remaining 48% is held by the consortium of private companies. FAW employs 12 people. It also administers a Point for Selective Collection of Municipal Waste.

The management and disposal of municipal waste collected within the city is, on the other hand, conducted by third-party entities selected through competitive proceedings by Frankfurter Dienstleistungsholding GmbH (which incurs the management and disposal costs). The amounts paid by Frankfurter Dienstleistungsholding GmbH for thermal disposal of waste range from €60 to 90 per Mg. The structure of tasks within the scope of waste management in Frankfurt an der Oder, has been illustrated below.

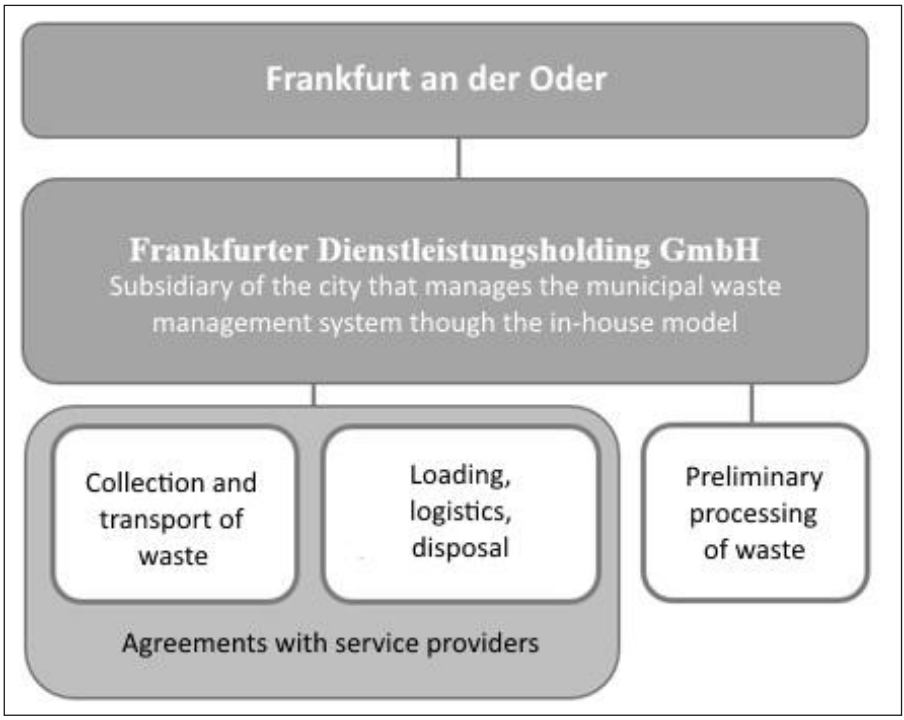

Diagram 8. The structure of the waste management system in Frankfurt an der Oder

Source: own analysis based on data from Frankfurter Dienstleistungsholding.

Fee for management of waste

The fees for management of municipal waste, paid directly by real property owners in Frankfurt an der Oder, are to cover the costs generated by collection and preliminary processing of such waste that the commune is liable for. The fees are collected by the Tax and Fees Department of the Financial Services Office (Amt für Finanzdienstleistungen), which comprises a part of the city hall.

The rate of the fees for waste management is determined, every year, by the City Council of Frankfurt an der Oder.

The collection system of packaging waste (light packaging and glass packaging) is financed, under separate rules, by the recovering organization Duales System Deutschland. Inhabitants of Frankfurt an der Oder must pay a multicomponent fee for waste management, pursuant to the act on rates of fees for

export of waste from the city of Frankfurt an der Oder dated 12 December 2017 (official journal, no. 10 dated 22.12.2017). An exemplary manner of charging a household using a 120 l container for accumulation of mixed waste with the said fee has been shown in Table 24.

Table 24. Fees for waste management in Frankfurt an der Oder

Type of fee	Container volume	Amount	Fee
Flat rate fee per container for mixed waste:	60 l	27.88	€/year
	80 l	37.18	
	120 l	55.76	
	240 l	111.53	
	1,100 l	511.16	
Fee for emptying 1 container:	60 l	1.47	€
	80 l	1.55	
	120 l	1.64	
	240 l	1.98	
	1,100 l	3.20	
Weight fee for the mass of collected mixed waste	n/a	0.12	€ / kg
Weight fee for the mass of collected bio-waste	n/a	0.15	€ / kg

Source: own analysis based on Gebührensatzung für die Abfallentsorgung der Stadt Frankfurt (Oder), Amtsblatt Nr. 10, 22. December 2017.

The fee is the total of all components specified above, for each container type. The fee for waste management is paid in advance, on a quarterly basis. The number of container emptyings is established on the basis of the actual number of emptyings in the previous year in the case of a particular real property. However, the minimum number of emptyings for mixed waste containers has been set at 12 per calendar year. The forecast fees for the mass of handed-over waste is calculated based on the actual amount of waste handed over by the real property owner in the previous year. If no data is available on the actual amount of waste handed over in the preceding year – the calculation utilizes the indicators for minimal waste accumulation at households: 100 kg per registered householder a year. The said determinations are (for the first time) made under a statement filed by the property owner.

Fees for additional, unscheduled export have also been introduced (for waste generated, among others, during exhibitions, events, fairs, etc.). The fees, for emptying 1 container, are as follows: 240 l - € 18.34; 1100 l - € 30.38.

The act has also introduced a fee for the customer's delivery of waste for processing. In the case of unsorted mixed municipal waste designated as 20 03 01, the fee equals 179.69 €/Mg.

3.2. Municipal waste management in the Czech Republic

In the Czech Republic, the task of managing municipal waste is attributed to communes. As its strategic document, the Czech Republic has been nowadays applying the waste management plan adopted at the end of 2014, which constitutes a natural continuation of the waste management plan established in 2003 (and applicable until 2013). It describes the waste management principles and determines target objectives throughout the duration of the document. The national waste management plan in the Czech Republic remains in force for 10 years. On an annual basis, the postulates stated in the plans are realized by the Ministry of the Natural Environment, while the supervisory effects are depicted in form of a report.

The most important legal acts with regard to waste management include:

- the act dated 15 May 2001 on waste and amendment to certain other acts (no. 185/2001 with further amendments) (Zákon ze dne 15. května 2001 o odpadech a o změně některých dalších zákonů),
- the Ordinance of the Minister for the Environment dated 17 October 2001 on details regarding waste handling (no. 383/2001, with further amendments) (Vyhláška Ministerstva životního prostředí ze dne 17. října 2001 o podrobnostech nakládání s odpady),
- the ordinance dated 23 March 2016 on waste catalogue (no. 93/216) (Vyhláška ze dne 23. března 2016 o Katalogu odpadu),
- act dated 4 December 2001 on packaging and amendment to certain other acts (no. 477/2001, with further amendments) (Zákon ze dne 4. prosince 2001 o obalech a o změně některých zákonů),
- ordinance of the Czech government dated 22 December 2014 on waste management plan of the Czech Republic for the period of 2015-2024 (352/2014) (Nařízení vlády ze dne 22. prosince 2014 o Plánu odpadového hospodářství České republiky pro období 2015-2024),

- other regulations regarding the manner of managing various types of waste.

Waste management is one of the most dynamically growing economic sectors in the Czech Republic. Since 2004 (the year in which the Czech Republic joined the EU), Czechs have implemented over 90% of European regulations into their domestic law. They created a system based on a rational approach towards issues connected with generation and disposal of waste.

The Czech Republic also effectively implemented the producer's liability rule in municipal waste management. Thus, covering the costs of managing selectively collected waste is one of the tasks of the recovering organization. It is achieved through cost reimbursement for communes, sorting plants, and other entities involved in the selective collection of municipal waste.

As part of their competences, communes in the Czech Republic stipulate, by way of a resolution, the principles for:

- collection,
- processing,
- disposal of municipal waste.

The aforementioned obligations can also be implemented through intermunicipal associations, as part of voluntary agreements between individual communes that comprise the association. Communes impose fees for collection of waste and maintenance of the infrastructure necessary to conduct municipal waste management that is in line with applicable regulations. In order to implement duties connected with municipal waste management, communes appoint, through public procurement or in-house mode, economic entities which render services within the scope of municipal waste management (such as waste export, recycling, etc.).

The current yearly amount of municipal waste generated within the Czech Republic equals approx. 5.7 million Mg. The ratio of municipal waste generation in the Czech Republic is at 537 kg/person per year. In 2017, according to the data of the Czech Ministry of the Environment (Ministerstvo životního prostředí), 50% of municipal waste generated in the country was subjected to recovery processes, 38% of which was recovered with the material method and 12% – with the energy method. In the end, 45% of the total stream of municipal waste was deployed to waste landfill sites, whereby that percentage value also covers waste generated during municipal waste recovery processes. The change in the streams of individual types of municipal waste in the Czech Republic has been illustrated in Charts 8, 9 and 10.

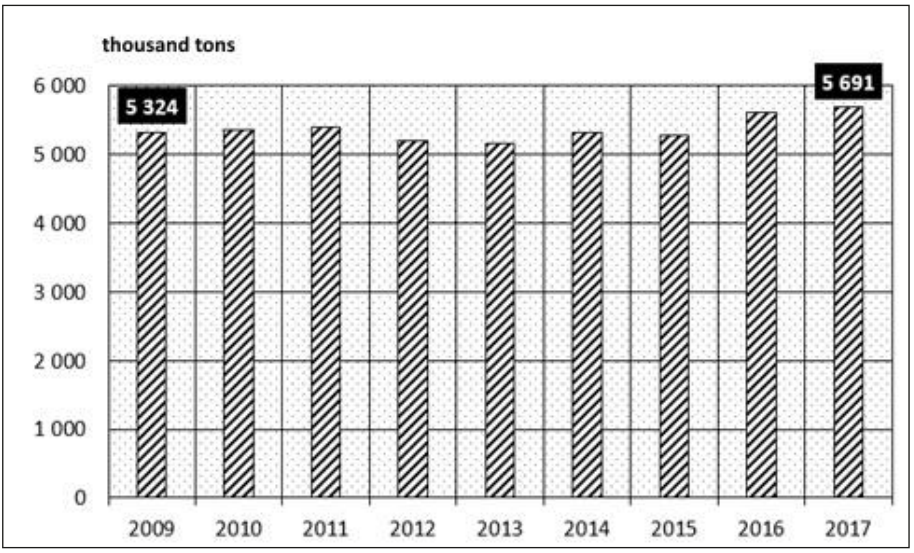

Chart 8. Changes in the stream of municipal waste in the Czech Republic, period of 2009-2017

Source: own analysis based on the data of the Czech Ministry of the Environment

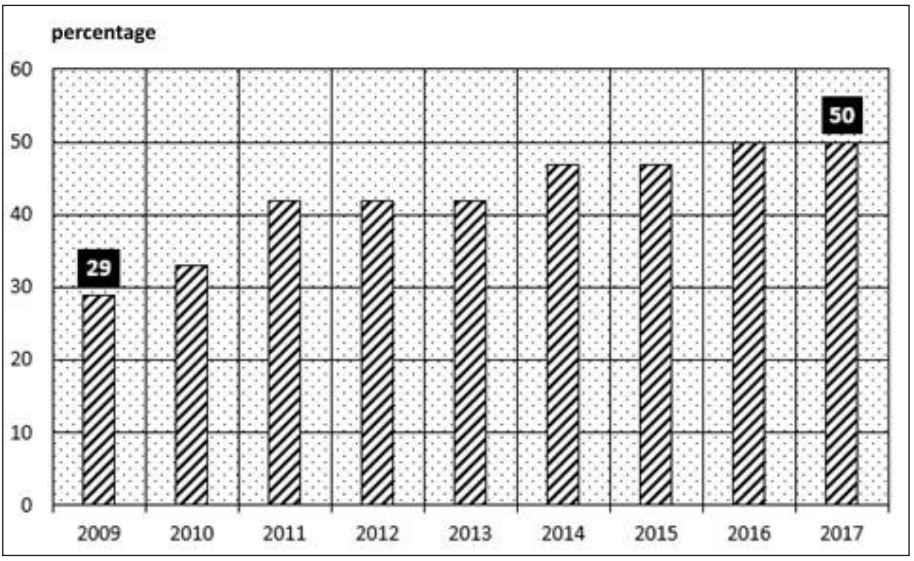

Chart 9. Growth of the percentage of municipal waste processed and subjected to recycling in the Czech Republic in the total amount of municipal waste, 2009-2017

Source: own analysis based on the data of the Czech Ministry of the Environment

The fraction composition of the stream of municipal waste collected in the Czech Republic has been depicted in Chart 10.

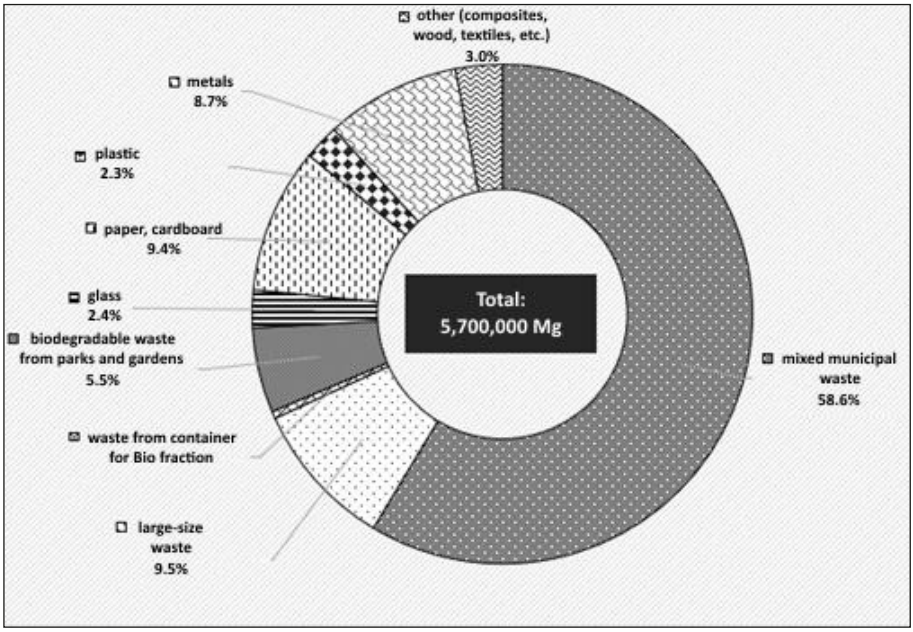

Chart 10. Percentage of individual fractions of municipal waste collected selectively in the Czech Republic in 2014

Source: own analysis based on: Plán odpadového hospodářství České republiky 2015-2024.

Waste management in Prague

Prague, which is the capital city of the Czech Republic, implemented a municipal waste management system that is commonly applied in that country. Key particulars characterizing the selected city have been presented in Table 25.

Table 25. Prague – general details on the city

City	Prague (Praha)
Population	1,262,507 (2015)
Area	496 km^2
Population density	2408 people/km^2

Source: own analysis.

The city of Prague is liable for ensuring collection and processing of municipal waste generated by its inhabitants. To serve such purpose, the city organizes tendering proceedings for collection and management of municipal waste from households. Waste is collected and managed by the company Pražské služby, a.s., which the capital city of Prague is the majority shareholder of. The company, based on a ten-year public procurement, is liable for collection and processing of municipal waste generated by inhabited real properties localized within the territory of Prague. In case of some districts, the company sub-contracts performance of duties connected with waste collection to private subcontractors that have their headquarters in respective districts, namely companies FCC, Komwag, AVE CZ, and IPODEC.

Management of municipal waste from Prague real properties which remain uninhabited yet generate waste is not subject to the factual power of the commune. Services for collection of waste from such real properties is realized under commercial rules, based on an agreement between the real property administrator and the company that collects the waste.

Collection and accumulation of waste

Selective collection of waste in Prague is structured on several tiers:

- "environmental islands" for selective accumulation of waste in public places,
- points for selective collection of waste,
- mobile points for selective collection of waste,
- mobile systems for collection of large-size waste; mobile systems for collection of organic waste,
- mobile systems for collection of hazardous waste,
- collection of other mixed municipal waste in containers for mixed waste located within real properties.

"Environmental islands" generally are facilitated with containers for:

- paper,
- plastic,
- glass,
- beverage cartons – Tetra Pak,

and some of them also include containers for:

- metals,

- textile products, and
- electronic devices.

Selective collection of municipal waste in the city of Prague is mandatory and based mainly on the network of so-called environmental islands, which in general are the equivalent of sorting nests that function in many Polish cities (like, e.g. Cracow). The network of environmental islands is relatively dense. When determining the localization of the network, it was assumed that the distance between the so-called islands and households should not exceed 150 m, while the maximum number of inhabitants per one island would not be higher than 300.

In most cases, "environmental islands" are equipped with typical MGB1100 containers made of plastic and handled with standard dustless vehicles with a rear-type loading system. On occasions, "bell" containers and underground containers are used; they are handled by vehicles with HDS cranes. Underground containers have mainly been used in locations that bear a historic value and require application of an esthetic waste accumulation system. The city of Prague keeps a thorough register of "environmental islands", including the assigned addresses; every record is assigned on the map in the GIS system and contains information on the number of containers, their type, availability, and frequency they are emptied at. The register is available on the following website: https://ksnko.praha.eu/map-separated/. Diagram 9 has presented an exemplary screenshot from the map screen of "environmental islands" with the record concerning the point shown above.

A crucial role in the Prague system of selective collection of municipal waste is also played by points for selective collection of municipal waste (Sběrné dvory). Each district in the capital city of Prague is facilitated with one point for selective collection of municipal waste to which registered residents of Prague can, free of charge (as a part of the already paid waste management fee), deliver waste accumulated in a selective manner, usually of size larger than the capacity of containers within "environmental islands" as well as large-size waste, rubble, electrical and electronic scrap, and similar waste. There are 22 such points in Prague and the number reflects the number of city districts.

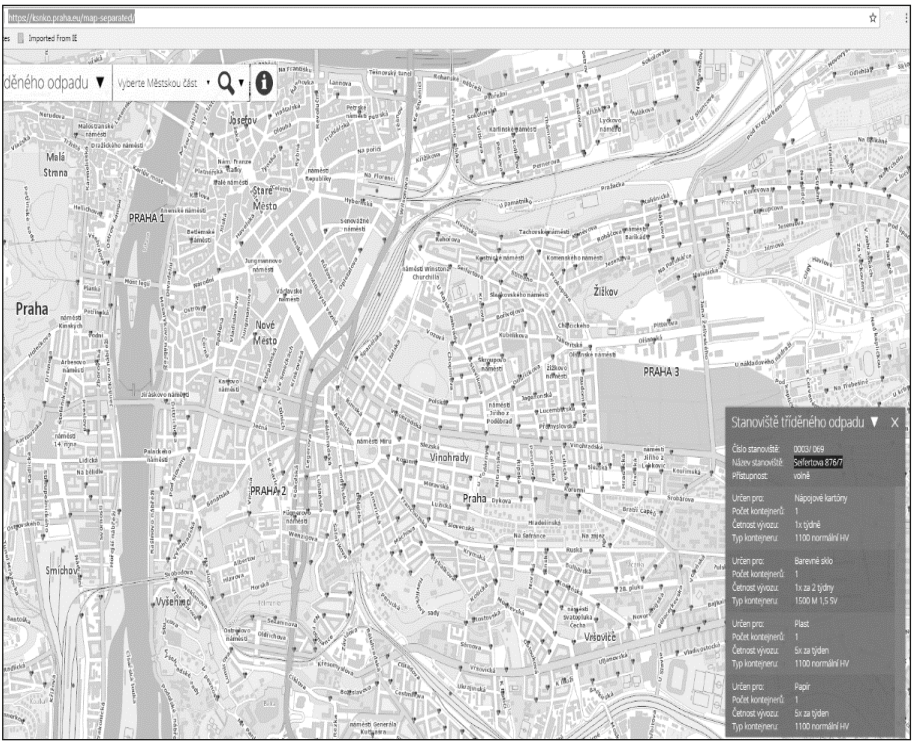

Diagram 9. A screenshot of the map of the "environmental islands" map with the record on the Seifertova 876/7 point

Source: ksnko.praha.eu/map-separated/ (DOA 28.11.2018).

Pursuant to the Resolution of the City Council of Prague no. 5/2007 – the commonly applicable disposition dated 26 April 2007 establishing the system for accumulation, transport, sorting, use, and disposal of municipal waste in the capital city of Prague and the system for management of construction waste [the so-called decree on waste] – (Obecně závazná vyhláška ze dne 26 dubna 2007, kterou se stanoví systénm shromažďování, sběru, přepravy, třídění,využívání a odstraňování komunálních odpadů vznikajících na území hlavního města Prahy a systém nakládání se stavebním odpadem – vyhláška o odpadech) and Resolution 2/2005 establishing the commonly applicable ordinance determining the fee for municipal waste (Obecně závazná vyhláška, kterou se stanoví poplatek za komunální odpad), each real property must have a container for accumulation of mixed waste.

The said resolution also specifies the minimum capacity of a container per 1 inhabitant, which should be declared by the real property administrator. The minimum volumetric ratio of waste accumulation was set at 28l/inhabitant on a weekly basis. In most cases, real properties are equipped with standard containers made of plastic.

Processing and disposal of waste in Prague

Prague has operating facilities that allow managing waste produced and collected in accordance with the waste handling hierarchy. The company Pražské služby a.s administers plants for sorting selectively collected municipal waste, composting waste, as well as a facility for thermal conversion of municipal waste. The sorting plant for paper, cardboard and Tetra Pak beverage boxes is located within the main headquarters of the company.

The plant is used for processing of all waste paper and cardboard and beverage boxes originating from selective collection of waste conducted at so-called environmental islands and at points for selective collection of municipal waste (regardless the company which collects the waste from inhabited real properties – every collector must transport such waste to the designated sorting plant). Furthermore, the facility sorts paper originating from uninhabited real properties, from which the said waste is exported by the company Pražské služby a.s.

Other type of raw material waste collected from "environmental islands" and points for selective accumulation of municipal waste are deployed to different waste managing companies which run sorting plants dedicated for processing of specific waste types.

Spółka Pražské služby a.s. is also the administrator of a thermal municipal waste processing plant (ZEVO – **Z**ařízení na **e**nergetické **v**yužití **o**dpadu – facility for energetic recovery of waste), which receives mixed municipal waste generated by all inhabited real properties in Prague and uninhabited real properties that produce municipal waste, covered by services of the company. The yearly throughput of the facility is 306,000 Mg. It also renders paid services of incineration of waste supplied by other waste managing entities or delivered by producers on their own.

Fee for management of waste

The fees for management of municipal waste generated by inhabited real properties in the city of Prague are incurred by owners of the said real properties through payment of a relevant amount to the bank account of the city. Entities which are obligated to pay the fees for management of municipal waste in favor of the city pay the relevant fee twice a year:

- by 15 June for the period from 1 January to 30 June,
- by 15 December for the period from 1 July to 30 December.

The rate for management of municipal waste is governed by the number and the volume of containers for mixed waste that are used by a particular real property. The fee covers all the costs related to municipal waste management, which is comprised of, i.a.: maintenance costs of points for selective collection of municipal waste, "environmental islands", collection of large-size waste, processing and disposal of waste. The rates for management of municipal waste applicable in Prague in 2018 have been quoted in Table 26.

Table 26. Rates of fees for municipal waste management in Prague [in Czech korunas]

Frequency	1 time per 2 weeks	1 time a week	2 times a week	3 times a week	4 times a week	5 times a week	6 times a week
Container volume	Fee in Czech korunas						
70 l	86	153	287	421	555	689	823
80 l	87	154	283	422	555	689	823
110 l	103	186	349	513	675	831	1,005
120 l	102	186	335	504	679	802	955
240 l	163	303	586	829	1,101	1,285	1,593
360 l	234	427	792	1,156	1,536	1,908	2,281
660 l	425	768	1,454	2,140	2,825	3,511	4,197
1,100 l	592	1,068	2,001	2,952	3,892	4,550	5,737

Source: own analysis based on www.praha.eu/file/904111/_2005_Sb._hl.m.Prahy (DOA 27.11.2018).

3.3. Municipal waste management in the Republic of Austria

The issues regarding waste management in the Republic of Austria have been already discussed in the basic law, which introduces the responsibility of the state, at federal level, for management of hazardous waste. The general rules of waste management in Austria have been regulated by provisions of the act on sustainable waste management (Gesetz über eine nachhaltige Abfallwirtschaft) which entered into force on 1 July 2002, as well as the implementing rules thereto. Within the scope of managing non-hazardous waste, the state is responsible for regulatory matters concerning waste management, limited to key competences such as:

- classification of waste,
- extended liability of the producer,
- collection of so-called problematic waste,
- collection of electrical and electronic scrap from private real properties and collection of used batteries and rechargeable batteries,
- processing and disposal of waste,
- collection of so-called municipal-like waste.

Other matters regarding waste management are governed by provisions of local acts on waste adopted by individual federal states. Federal states are, primarily, responsible for regulations concerning collection of municipal waste, relevant collection of fees for waste, and for planning the locations of facilities used to process municipal waste. In this regard, all nine federal states issued their own acts on waste. In some cases, implementing rules were introduced as well. Usually, the national act on municipal waste management or the relevant regulations stipulate provisions which refer to the following areas of interest:

- collection and management of mixed municipal waste, large-size waste, biodegradable waste,
- planning waste management at federal state level (along with issues concerning prevention of waste production),
- instructions for informative and educational activities for the inhabitants,
- instructions for municipal terms regarding maintenance of cleanliness and order,

- obligations of real property owners in the scope of municipal waste management,
- mandatory collection of municipal waste,
- regulations concerning determination and collection of fees for management of municipal waste by communes.

The obligations of public authorities at respective levels within the scope of municipal waste management in Austria have been presented in Table 27 below.

Table 27. Tiers of liability for municipal waste management in Austria

Type of waste	Liability for regulations regarding accumulation and processing	Liability for organizing the accumulation	Liability for organizing the processing and recovery
mixed waste	federal state	commune (or commune union)	commune (or commune union) / federal state
large-size waste	federal state	commune (or commune union)	commune (or commune union) / federal state
biodegradable waste	federal state	commune (or commune union)	commune (or commune union)
(non-packaging) paper	federal state	commune (or commune union)	commune (or commune union)
(packaging) paper	the state	operator placing on the market	operator placing on the market
(packaging) glass	the state	operator placing on the market	operator placing on the market
light packaging	the state	operator placing on the market	operator placing on the market
metal packaging	the state	operator placing on the market	operator placing on the market
other metal waste	federal state	commune (or commune union)	commune (or commune union)
problematic waste	the state	commune (or commune union)	commune (or commune union)
used electrical and electronic equipment	the state	commune (or commune union)	the industry (placing on the market)

Source: own analysis based on the federal municipal waste management plan 2017.

Every 6 years, when implementing the requirements arising from provisions of the act on sustainable waste management and from community regulations, Austrian government publishes a federal plan of waste management within the country, which describes the targets concerning management of individual types of waste, implementation of the hierarchy of waste handling methods, the proximity rule, and maintenance of a proper waste management facility system in the country. The most recent plan was adopted in December 2017.

The current yearly amount of municipal waste produced in the Republic of Austria is approx. 4.3 million Mg. The ratio of municipal waste generation in Austria is at 486 kg/person per year. In 2015, according to information of the Federal Ministry of Sustainable Development and Tourism (Bundesministerium für Nachhaltigkeit und Tourismus), recovery processes covered 67% of municipal waste generated in the country. Only 3.3 thousand Mg out of the total stream of municipal waste was deployed to waste landfill sites. The changes in the stream of municipal waste in Austria have been presented in Charts 11 and 12.

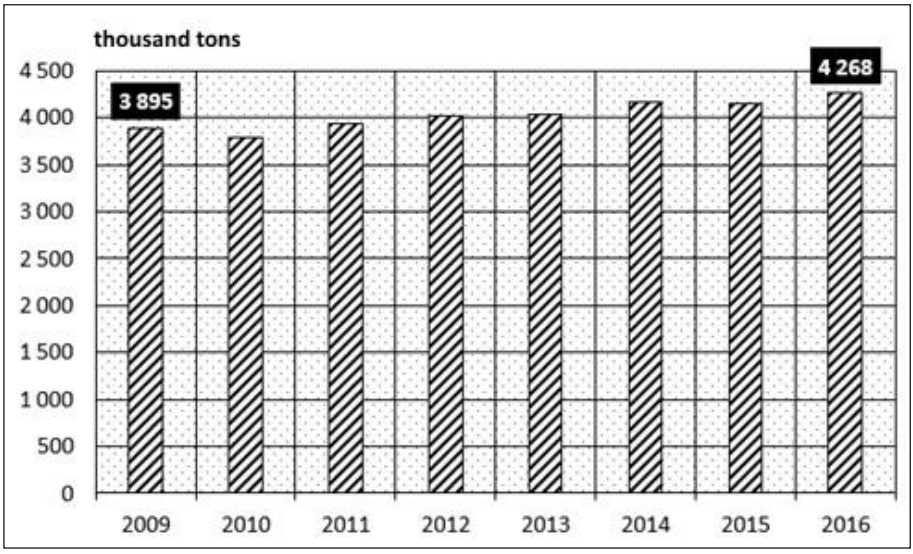

Chart 11. Changes in the stream of municipal waste in Austria, years 2009-2016

Source: own analysis based on the preventive program for waste generation (Abfallvermeidungsprogramm 2017).

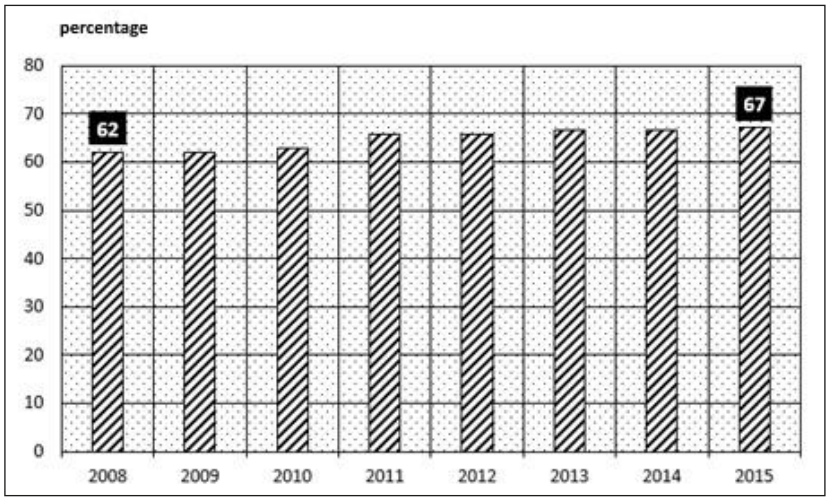

Chart 12. Changes in the percentage of municipal waste processed and subjected to recycling in Austria in the total amount of municipal waste, 2008-2015

Source: own analysis based on the data of the European Environmental Agency.

The raw material composition of selectively collected municipal waste in Austria has been presented in Chart 13.

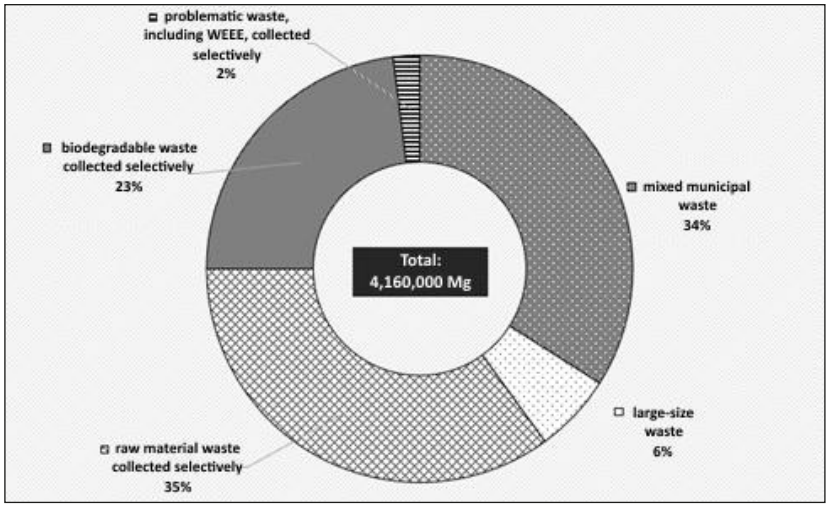

Chart 13. Percentage of individual fractions of municipal waste collected selectively in Austria in 2015

Source: own analysis based on: Bundes-Abfallwirtschatfsplan, 2017.

Waste management in Vienna

Vienna, the capital city of the Republic of Austria, realizes a municipal waste management system similar to systems functioning in all large Austrian cities. Key particulars characterizing the selected city have been presented in Table 28.

Table 28. Vienna – general details on the city

City	Vienna (Wien)
Population	1,840,573 (2015)
Area	415 km^2
Population density	4,436 people/km^2

Source: own analysis.

Full responsibility for managing municipal waste produced within Vienna is attributed to the city. Municipal waste constitutes the property of the city. All duties regarding waste management, starting from maintaining and administering the system, collecting municipal waste from real properties, sorting hubs and points for selective collection of waste, to organization of processing and disposal of municipal waste are performed by the 48th Department of the City Hall in Vienna (Magistratabteilung 48, in short: MA48). Management of municipal waste is conducted in exchange for a fee paid by real property owners on municipal waste management, which constitutes a non-tax local charge. Diagram 10 has illustrated the management of municipal waste in Vienna.

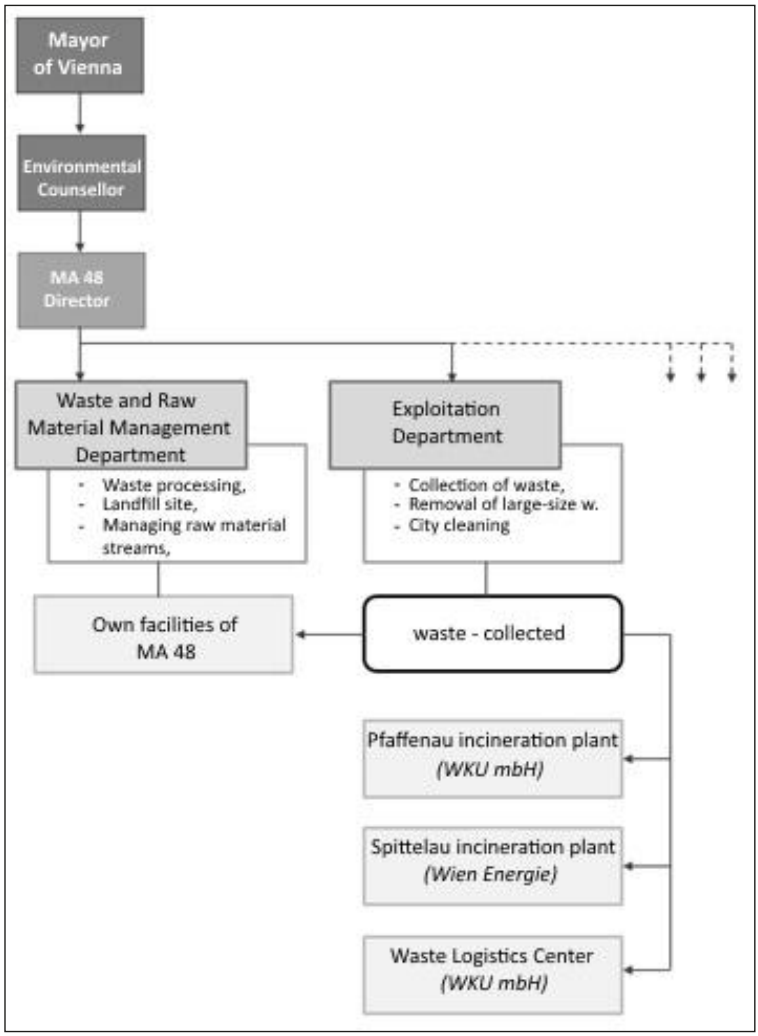

Diagram 10. The diagram illustrating management of municipal waste in Vienna

Source: own analysis based on the annual statement of MA48 for 2017.

Collection and accumulation of waste

Selective collection of waste in Vienna is structured on several tiers:

- Selective collection of waste within real properties, in containers used to accumulate:
  – paper,

  - biodegradable waste, and
  - mixed waste;
- "Environmental islands" for selective accumulation of waste in public places:
  - organic waste,
  - paper,
  - glass,
  - metals,
  - plastic;
- Points for selective collection of waste;
- Mobile systems for collection of large-size waste.

The majority of municipal waste within real properties is accumulated in containers of capacity not lower than 110 l, adjusted to the number of users. "Environmental islands" are equipped with typical MGB1100 containers made of plastic and handled with standard dustless vehicles with a rear-type loading system. Points for selective collection of municipal waste (a total of 18 units) are facilitated with a system of bins and containers allowing accumulation of any type of municipal waste, along with large-size and construction waste of municipal origins. Any municipal waste delivered by inhabitants are accepted at points for selective collection free of charge, except for mixed waste, which are subject to a fee. Certain points for selective collection of municipal waste in Vienna, apart from the standard collection of waste, offer, e.g.:

- book exchange service,
- free collection of small amounts of compost produced from municipal waste accumulated in the city,
- forwarding used items in good condition or brand-new items (e.g. furniture, lamps, interior decorations, unused wall paints, etc.) to new users,
- handing over items repaired at the workshop being an integral part of the point for selective collection of waste.

Processing and disposal of waste in Vienna

In Vienna, there are facilities capable of managing the generated and collected municipal waste in accordance with the waste handling hierarchy and the proximity principle. In general, mixed municipal waste, which constitutes

the remaining, non-raw material portion of selective collection, is subjected to thermal conversion at plants for thermal conversion of waste with energy recovery: Pfaffenau, Spittelau, and Flötzersteig. The total capacity of Vienna facilities for thermal processing of waste is 780,000 Mg/year. In 2017, thermal conversion covered a total of 740,000 Mg of waste, where 522,000 Mg constituted mixed waste collected from inhabited real properties. The biodegradable waste collected within Vienna is deployed for biological processing at the facility of anaerobic processing of waste, Biogas Wien, and to Lobau composting plant. Moreover, the thermal waste conversion and biogas plant Biogas Wien neighbors with the Waste Logistics Center which sorts municipal waste and packs waste in order to ensure optimized and uniform deliveries to individual facilities. Waste processing facilities are generally administered by entities dependent on the city – either at own plants of MA 48 (Rinterzelt waste processing facility, Lobau composting plant) or of the subsidiary of MA 48 – WKU Wiener Kommunal-Umweltschutzprojektgesellschaft mbH (Pfaffenau incineration plant, Waste Logistics Center, Biogas Wien), or the heating company Wien Energie (Spittelau and Flötzersteig incineration plants).

Fee for management of waste

The fees for management of municipal waste generated by inhabited real properties in Vienna are incurred by the owners of the said real properties through payment of a fee for waste management to the bank account of the city. Entities which are obligated to pay the fee for management of municipal waste pay the relevant amount on a quarterly basis: by 15 February, by 15 May, by 15 August, by 15 November.

The rate for management of municipal waste is governed by the number and the volume of containers for mixed waste that have been made available by the city to be used at a particular real property. The fee is the product of the following elements: the number of provided containers, the yearly container emptying frequency, and the flat rate fee for one container emptying according to a particular volume.

The fee covers all the costs related to municipal waste management, which is comprised of, i.a.: maintenance costs of points for selective collection of municipal waste, "environmental islands", collection of large-size waste, processing

and disposal of waste. The amount of the flat rate fee in 2018 for one container emptying according to a particular size has been shown in Table 29.

Table 29. Amount of the flat rate fee for single emptying of a container in Vienna [EUR]

Container volume	120 l	240 l	770 l	1,100 l	2,200 l	4,400 l
Fee for single emptying	4.56	9.12	31.92	45.6	91.2	182.4

Source: own analysis based on https://www.wien.gv.at/hausmuell.html (DOA 29.11.2018).

The minimum container emptying frequency, pursuant to the Vienna act on waste (Wiener Abfallwirtschaftsgesetz), is 34 times in a year. The amounts of the yearly fee for management of municipal waste, depending on various container emptying frequencies, have been listed in Table 30.

Table 30. Yearly fee for waste management in Vienna depending on the container volume and emptying frequency [EUR]

Annual emptying frequency	120 l	240 l	770 l	1,100 l	2,200 l	4,400 l
34	155.0	310.0	1,085.2	1,550.4	3,100.8	6,201.6
52	237.1	474.2	1,659.8	2,371.2	4,742.4	9,484.8
68	310.0	620.1	2,170.5	3,100.8	6,201.6	12,403.2
102	465.1	930.2	3,255.8	4,651.2	9,302.4	18,604.8
104	474.2	948.4	3,319.6	4,742.4	9,484.8	18,969.6
156	711.3	1,422.7	4,979.5	7,113.6	14,227.2	28,454.4
208	948.4	1,896.9	6,639.3	9,484.8	18,969.6	37,939.2
260	1,185.6	2,371.2	8,299.2	11,856.0	23,712.0	47,424.0
312	1,422.7	2,845.4	9,959.0	14,227.2	28,454.4	56,908.8
364	1,659.8	3,319.6	11,618.8	16,598.4	33,196.8	66,393.6
416	1,896.9	3,793.9	13,278.7	18,969.6	37,939.2	75,878.4
624	2,845.4	5,690.8	19,918.0	28,454.4	56,908.8	113,817.6
936	4,268.1	8,536.3	29,877.1	42,681.6	85,363.2	170,726.4

Source: own analysis https://www.wien.gv.at/umwelt/ma48/tarife/hausmuell.html.

The analyzed cities in Germany, the Czech Republic and Austria feature a diversified yet advanced systems for organization and management of municipal waste. In the vast majority of analyzed cities, the municipal waste management facilities constitute the property of and are exploited by entities with communal involvement. Entities liable for collection of waste and administra-

tion of the waste collection system also serve as the operator of the facility for thermal conversion of municipal waste.

Comparisons between organization and management of municipal waste in the analyzed Polish and foreign cities are problematic in face of diversified statistics and applied measurement methods, e.g. for the achieved levels of recycling. Municipal self-governments in Poland, however, learn about the foreign technical, organizational and management solutions, which can be exemplified by the municipal waste management systems in Cracow or Białystok.

Chapter 4.

THE EFFECTIVENESS OF MUNICIPAL WASTE MANAGEMENT IN COMMUNES AND COMPANIES - RESULTS OF EMPIRICAL STUDIES

4.1. Municipal waste management in communes in terms of technical and exploitation and financial aspects

In this chapter, an attempt was made to assess the effectiveness in the area of municipal waste management based on the example of selected companies and communes they operate in.

The survey covered 38 communes (Diagram 11) representing capital cities of individual voivodeships, large cities, localities in Małopolskie Voivodeship, and communes that apply the in-house model. Based on publicly available data, an empirical database was elaborated to analyze waste management. Information was gathered based on the data included in reports drawn up by the commune administrator, city mayor or president on implementation of tasks regarding management of municipal waste for 2018. The information is available on the public information bulletin website of respective communes. What is more, the study utilized information from official websites of the analyzed communes and the companies serving the communes within the scope of municipal management. In order to analyze the effectiveness of municipal

waste companies, a questionnaire was elaborated to survey municipal waste management in a commune (Attachment 1).

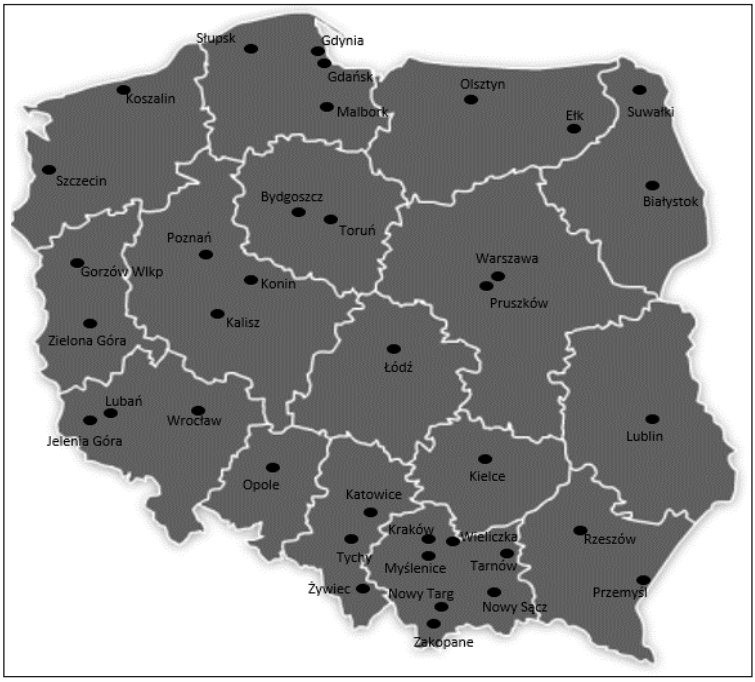

Diagram 11. Communes selected for studies regarding municipal waste management

Source: own analysis.

The respondents should answer the questions stated in the questionnaire within the period from 15 April to 15 May 2019, pursuant to Art. 8 of the act dated 3 October 2008 on publishing information about the environment and its protection, public participation in the environmental protection and environmental impact assessment, as well as Art. 2 section 1 and Art. 10 section 1 of the act dated 6 September 2001 on access to public information[99]. Partial information was obtained from 23 communes (60.5% of the test). Out of 15 communes that did not fill in the questionnaire, only 1 commune applies the in-house solution.

[99] Polish Journal of Laws 2001 no. 112 item 1188 with further amendments.

According to the findings made in Chapter 1, the questionnaire (Attachment 1) drew attention to the fact that communes are obligated to reach recycling levels of and prepare to reuse the following fractions of municipal waste: paper, metal, plastic, glass, and construction and demolition non-hazardous waste, constituting municipal waste in amounts provided for in separate regulations. Such regulations have been introduced in order to force changes in the waste management system to follow the direction set by the European Parliament in the waste management hierarchy (see Diagram 1), according to which reusing and recycling of materials is more preferable than other waste processing methods (incineration, storage). From the point of view of system effectiveness, a possibly high level of recycling should be achieved at a possibly low execution of resources. Thus, the questionnaire includes questions regarding the unit cost of operations of the municipal waste management system with regard to the achieved level of recycling. It indicates the extent of financial resources used to achieve the levels of recycling. The conducted investigation has drawn attention that points for selective collection of municipal waste (PSZOK) form a crucial element of communal waste management systems. Communes must establish them within their territory in light of the act on maintaining cleanliness and order... (Art. 3 section 2 point 6). Points for selective collection of municipal waste help the inhabitants dispose of some types of waste (electrical devices, large-size waste, hazardous waste, raw material waste, etc.) in a way that allows further, selective management of such waste. As a result, it reduces the percentage of such waste in mixed waste and increases the percentage of waste sent for recycling or to be reused. The greater the amount of waste collected at a point for selective collection of municipal waste per one inhabitant of the commune, the more efficient the waste management system proves to be.

Management of municipal waste in communes, from a financial point of view – the fee for municipal waste management and its relation to the budget of the commune, rules governing the structure of the revenue and expenditures in the budget of the commune, and the place of connecting them with fees for waste management – is a sophisticated matter. According to Chapter 1, financing of a municipal waste management system in a commune has been currently based on a public law fee for managing municipal waste. The fee is paid by entities that hold the status of real property owners and it, generally, constitutes the income of the commune. The income on fee for municipal waste manage-

ment is not subject to the general non-funding principle stipulated in Art. 42 section 2 of the act on public finance, according to which public funds originating from individual sources must not be used for financing of specifically determined expenses, unless it is provided for in a separate act[100]. Funds from the fee for managing municipal waste, pursuant to the act on maintenance of cleanliness and order in communes, have a "designated character" and can be utilized only for purposes provided for in the act, i.e. for financing costs related to the functioning of a municipal waste management system. Financing of public procurement for collection of municipal waste or collection and management of such waste constitutes an important element of the said system. When the acquired proceeds from the fee exceed the expenses (costs of the system), the surplus should be solely used to finance the system in the next financial year. However, verification of fee rates will be then obligatory to ensure proper financing of the system. The concept of the municipal management system in Poland is characterized by its self-financing character, i.e. financing of planned costs of the system through fees for managing municipal waste. As part of this elaboration, financial information for analyzed communes has been obtained. The following information has been subjected to comparison: income of commune from the fee for managing municipal waste – assigned according to relevant statements, monetary proceeds to the budget of the commune from municipal waste management fees, and the total current income of the commune. Furthermore, the value of current expenditures incurred by communes for the municipal waste management system has been determined, including the following breakdown: expenses for collection, transport, accumulation, recovery and disposal of municipal waste, expenses for establishing and maintaining points for selective collection of municipal waste.

4.2. Formulation of the basic financial data in municipal waste management companies

The study selected 52 companies that serve a dominating role within the area of 38 distinguished communes. Similarly, to the case of cities, a questionnaire was to be the basic source of information required to determine

[100] Act dated 27 August 2009 on public finances, Polish Journal of Laws, item 2077 Art. 42.

the effectiveness of companies (attachment no. 2). Replies were provided only by 2 entrepreneurs, while the whole questionnaire was completed by 1 company. Thus, the assessment of effectiveness of companies operating in the sector of municipal waste management was performed based on financial statements filed in the National Court Register, mainly with regard to their financial outcome. Among analyzed entities, there are 9 communal companies that render their services under an entrustment agreement, so-called in-house, as well as 43 municipal and private undertakings selected through a tendering procedure. Table 31 has demonstrated a synthetic analysis of general items in the balance sheet and the profit and loss account of analyzed companies, by their operating method, in 2018.

nt companies are characterized by a high share of fixed assets, a relatively low level of foreign financing sources, and profits on conducted activity. As the analysis of values suggests, based on the basic central measure (median), in-house companies generate half the revenue compared to other studied companies. Regardless, the highest revenue in 2018 was achieved by an entity representing that particular group. Among the distinguished company groups, the revenue of in-house enterprises equals only 17.47% of the total value. Detailed analyses of the revenue generated by analyzed companies, according to their organizational and legal forms, size and localization, have been presented in Table 32. Limited liability companies form over 85% of revenue in the group of analyzed entities. When considering their size, 21 medium-sized companies constitute over 61% of the revenue. What is peculiar, the group of large companies (comprised of two examples) generates a revenue very similar to 29 small and micro companies. The highest revenue is achieved by entities operating in specific cities of Małopolskie Voivodeship, which is most certainly determined by the number and size of analyzed entities from that area.

Table 31. The analysis of basic items of the balance sheet and the profit and loss account of analyzed companies in 2018 [in millions of PLN]

Specification	Fixed assets	Current assets	Total assets	Equity	Long-term liabilities	Short-term liabilities	Total liabilities	Net profit	Net revenue on sales
In-house companies	432.17	83.82	515.99	238.12	74.39	102.55	176.93	4.78	457.21
Percentage - in-house companies [%]	8.19	7.91	8.14	11.00	5.39	11.57	7.81	3.13	17.47
Companies rendering services under a won tender	4844.95	975.89	5820.84	1927.10	1305.19	783.57	2088.76	148.20	2160.22
Percentage - companies rendering services under a won tender [%]	91.81	92.09	91.86	89.00	94.61	88.43	92.19	96.87	82.53
Total - all companies	5277.12	1059.71	6336.83	2165.22	1379.58	886.11	2265.69	152.99	2617.43
Median - in-house companies	33.83	4.75	41.32	28.21	3.98	3.90	6.73	0.32	21.31
Median - companies rendering services under a won tender	48.77	14, 83	63.90	29.66	6 ,47	9.86	21.73	1.49	44.96
Median - all companies	41.30	4.75	52.61	28.93	3.98	6.88	14.23	0.91	33.14
Maximum value - in-house companies	189.43	41 ,79	223.35	84.96	39.07	78.50	117.57	4.62	297.72
Maximum value - companies rendering services under a won tender	796.80	122.97	839.09	298.79	355.16	145.26	499.98	22.44	224.38

Source: own analysis.

Table 32. The structure of revenue of analyzed companies by organizational and legal form, amount of revenue, and area of operations in 2018

Division criteria	Type of company		Number of companies	Share in the total value of revenue [%]
Organizational and legal form	Limited liability companies		48	85.98
	Joint-stock companies		4	14.02
Revenue*	Micro		5	1.77
	Small		24	18.17
	Medium		21	61.04
	High		2	19.02
Area of operations**	Voivodeship	Małopolskie	12**	21.77
		Podkarpackie	2	2.70
		Śląskie	3	5.48
		Opolskie	1	1.21
		Dolnośląskie	6**	8.73
		Lubuskie	1	1.01
		Wielkopolskie	6**	10.89
		Łódzkie	2	2.01
		Świętokrzyskie	2	4.62
		Lubelskie	1	1.84
		Mazowieckie	4**	15.93
		Kujawsko-Pomorskie	1	1.80
		Zachodniopomorskie	3	5.94
		Pomorskie	6	10.12
		Warmińsko-Mazurskie	2	0.83
		Podlaskie	4	5.12

* Applied criterion of amount of revenue on sales - turnovers for: micro - below EUR 2 million, small - from EUR 2 to 10 million, medium EUR 10 to 50 million, large - over EUR 50 million, at exchange rate of EUR 1 = PLN 4.27.

** ALBA SA, ENERIS EKOLOGICZNE CENTRUM UTYLIZACJI Sp. z o.o., SUEZ Polska Sp. z o.o., REMONDIS Kraków Sp. z o.o. operate within the area of more than one of the analyzed cities. The revenue of those companies was presented proportionally by individual voivodeships.

Source: own analysis.

Based on the conducted analysis, it may be concluded that there have been significant discrepancies in the profits achieved by selected entities. In the case of the more numerous study group, the values indicate a total average of about PLN 1.5 million compared to several hundred thousand zlotys of average profit

achieved by the second study group. International concerns invested hundreds of millions of Polish zlotys in Poland, which however does not reflect the central tendency, since the values, for both populations, are at a similar level and amount approx. PLN 28 million. Suez Zielona Energia Sp. z o.o. owns fixed assets worth nearly PLN 800 million; nevertheless, individual cases do not fully translate into the general picture, since the median difference is about PLN 15 million. As for current assets, there is a larger disproportion favoring companies that operate on a tender basis. Here, it should be added that entities outside the system of in-house services utilize short-term and long-term financing sources to a several times greater extent. Such an inequality is reflected in measures of the central value, as well as in maximum values.

According to an analysis of individual values, in-house companies are characterized by a much smaller volume of financial values. Similarly to the assessment based on the number of individual entities, the analysis of fundamental financial values indicates that entrustment model solutions are uncommon in Poland. Apart from MPO Sp. z o.o. in Kraków, the rest of entities in that group must be qualified as medium-sized and small companies in the sector of municipal waste management. The achieved financial values are at a level lower than in the case of, e.g. private entities rendering services under a tender won in a particular commune.

4.3. Studies regarding effectiveness within the area of the municipal waste management system

In the situation of market economy, entities are obligated to effectively utilize their owned financial, material, and personal resources as well as to acquire new and maintain the current customers, enhance technological processes, and manage their business in an efficient manner. It requires determining whether the conducted business activity brings intended effects as well as indicating directions for future development. Such approach is combined with the notion of effectiveness, which must be understood as the best performance in production and distribution of goods and services at specific costs or the lowest possible costs for particular effects. Furthermore, it can be brought to rational management, i.e. in business activity, one must operate in such a way that given specific measures they achieve the maximum degree of implementation of the goal or, given particular

progress, consume as little resources as possible. In such cases, effective activity then involve application of one out of two principles of rational management, i.e. the rule of maximization of obtained results with owned resources or the rule of minimization of incurred funds and costs for implementation of the scheduled tasks.

Effectiveness may be considered in terms of various aspects of the management process (Diagram 12), i.e. from the technical, economic, or environmental point of view, etc. Companies that render public utility services (e.g. municipal waste management), compared to other companies, are subject to additional liability to a certain community. Thus, another type of effectiveness can be distinguished – social effectiveness[101].

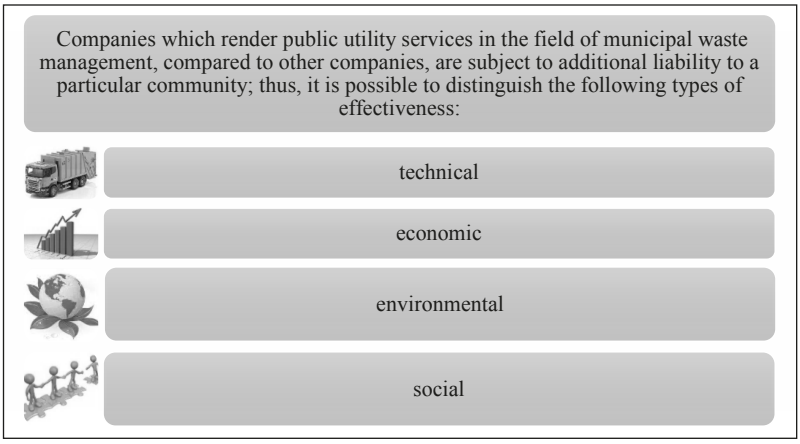

Diagram 12. Effectiveness of municipal waste management companies

Source: own analysis.

In this sense, in order to ensure reliability and efficiency of waste management in a city, one must not rely solely on economic indicators for a company. The effectiveness of activities of public utility nature may be measured with regard to three points of reference (Diagram 13): the direct producer or supplier, i.e. the public utility company; organizer of the public utility services market, i.e. the local authorities (most often the commune); and the consumer of such goods (inhabitant of a particular city). The analysis made in this elaboration has referred to the perspective of a company and a commune.

[101] K. Wąsowicz, *Efektywność przedsiębiorstw użyteczności publicznej lokalnego transportu zbiorowego*, Fundacja Uniwersytetu Ekonomicznego w Krakowie, Cracow 2018, p. 68, 101.

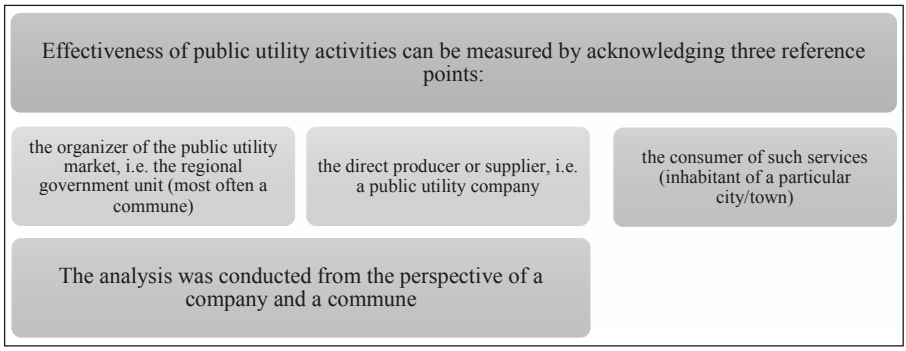

Diagram 13. Measurement of effectiveness of public utility activities

Source: own analysis.

The assessment of effectiveness of the waste management system in the analyzed communes has been conducted on the basis of an assessment regarding the degree of collection of the fee for managing municipal waste, the adequacy of the fee for managing municipal waste, and the distribution of current expenditures of analyzed communes on the system. The achieved levels of recycling are a very significant indicator of effectiveness – the quality of waste management in a particular commune. Although most local governments seem to seamlessly satisfy the required levels regarding construction and demolition waste, the raw material fraction (paper, metal, plastic, and glass) poses a technological and organizational challenge for the communes. One can, without a doubt, conclude that the higher the level of recycling for the fraction of raw materials in a particular year in the commune, the more effective and efficient the waste management system is. The dynamics of increase in levels of recycling for the raw material fraction and for construction/demolition waste is also a significant indicator – it shows the degree under which the share of waste subjected to recycling in a particular commune has changed throughout the years. The high value of this indicator informs on modernization of the waste management system in the commune towards more efficient recycling and preparation for re-usage. It should be noted that in the forthcoming period the obligatory levels of recycling expected in the case of the raw material fraction are to increase by 10 p.p., up to a value of 50% in 2020, which is very problematic for communes and their waste management systems. From the point of view of system effectiveness, the possibly high level of recycling should be achieved at a possibly low execu-

tion of resources. Thus, comparing the unit cost of operations of the municipal waste management system with the degree of recycling indicates the amount of financial resources necessary to achieve the levels of recycling.

Points for selective collection of municipal waste (Polish abbreviation: PSZOK) stand for a strategic element of communal waste management systems. The greater the amount of waste collected at a point for selective collection of municipal waste per one inhabitant of the commune, the more efficient is the waste management system. The proposition of an indicator determining expenditures of the commune to organize points of selective collection of municipal waste, calculated per capita, should express the "involvement" of the commune in the increase in selectively accumulated waste that can be used in the processes of recycling and preparation for re-usage. Determination of expenditures on points for selective collection of municipal waste, with regard to the amount of waste ending up at PSZOKs, illustrates the effort and resources needed to collect waste at such points (a lower value of this relation stands for greater efficiency of selective collection compared to incurred costs). However, one should highlight that effects of resources spent on points of selective collection of municipal waste can often become noticeable after some time from the date of their establishment, since the efficiency of operations of such element of the waste management system in a commune is also influenced by the approach of the society, which must be properly shaped through relevant educational activities.

The effectiveness of municipal waste management companies has been determined based on a ratio analysis of available financial data (lack of technical and exploitation data). Central values for the two studied groups have been listed in Table 33. In the case of a company operating in the field of municipal waste management, revenue is the general financial category. Revenue on sales of services reflects the value of generated and payable amounts resulting from sales of services conducted by entrepreneurs in favor of organizers (such a situation occurs if in a particular system of organization and management of municipal waste the function of the organizer is separated from the function of the service supplier). The regulators of local governments decide on the prices and fees as well as the method of determining the said prices and fees for public utility municipal services and for the use of structures and equipment of public utility owned by local government bodies.

Table 33. The median of financial ratios of municipal waste management companies functioning in the distinguished communes in 2018

Spec-ific-ation	Sales profit. [%]	Assets profit. [%]	Equity profit. [%]	Payment cycle of short-term liab. in days	Total use (rotation) of assets	Current financial liquidity	Debt ratio [%]	Percentage of equity in asset financ.	Equity / Third-party equity	Percentage of foreign service cost in oper. costs	Financial costs / Total liabilities	Fixed assets / Total assets
Median repres. without in-house	3.74	2.90	6.33	87.14	0.75	1.24	35.95	0.47	1.50	0.35	0.03	0.74
Median repres. in-house	0.73	0.39	0.43	59.70	0.86	1.41	23.13	0.63	2.64	0.23	0.02	0.82

Source: own analysis.

The cost of offered services must be structured in a way that is socially acceptable by the members of the self-governmental community and, simultaneously, adequately to costs incurred by a company that satisfies the basic needs of the local population.

It is conceivable to compare groups of ratios which illustrate useful, important standards of financial operations of municipal waste management system companies in the aspect of revenue, costs, and income. Those are profitability ratios which, due to their synthetic nature, find application in the assessment of effectiveness of an entity. Profitability ratios communicate the effectiveness of operations and express the relation of the profit calculated at various tiers of economic activity to: the generated revenue on sales of products, properties (assets), equities, or, e.g. size of employment. Due to the specific social role of public utility companies, the primacy of generated profit is inconclusive. When formulating the definition of public utility service, we might indicate – guided by linguistic interpretations – that such activity is to contribute to the general public and it is not aimed at maximization of profits. According to that statement, the ratio of accumulated profit of companies operating within a particular commune to the size of expenses on a waste management system should fall within a specific limited range.

The return on equity ratio is the most adequate measure of advantages achieved by owners of such a business entity. It identifies the effectiveness of invested equity. Bearing in mind the fact that, in the case of market economy, capital can be invested in various undertakings, the possibility to assess the effectiveness of its investment in particular undertakings is of crucial significance for the owner of such capital. Another group of indicators that creates a chance to compare the effectiveness of companies in the sector of municipal waste management is the group of financial indicators regarding the efficiency of operations, also called activity indicators. The activity indicator, connected with the use of assets, was distinguished. It specified the effectiveness of assets. The indicators can be interpreted in two ways: they determine the turnovers achieved with the average state of assets for implementation of target sales; they show the value of sales achieved by involving PLN 1 of fixed assets, current assets, or total assets. The higher the sales value achieved from involved equity, the higher the effectiveness of the company. As it may be concluded from the conducted analysis, the average value of that indicator is higher when referred to in-house companies.

Public utility companies owned by a regional government unit are covered by protection against two hazards which also discipline the managerial processes in private entities, i.e. protection against being taken over and against bankruptcy. Thus, it is also appropriate, when determining the effectiveness of management, to assess the ability of a company to pay its liabilities. The total debt ratio acknowledges all liabilities. The lower the ratio, the lower the financial risk upon incurring further loans. Simultaneously, one must be aware that a company which uses foreign sources of financing increases the earning power of equities. From that perspective, an increased in the percentage of debts in the structure of liabilities might prove to be a positive phenomenon. On the other hand, however, debt involves payments linked to debt service. Therefore, if a company achieves low financial performance, there might occur an actual threat to its further functioning. Summing up, the higher the percentage of debt in the structure of liabilities, the higher the financial risk.

As it is indicated by the median calculated for the debt ratio of distinguished company groups, in-house companies represent a more stable situation. They do not utilize the so-called financial leverage (an income effect related to the change in return on equity by utilizing third-party equity). In-house companies, however, incur relatively low financial costs with reference to total liabilities, which undeniably is a more effective measure.

In order to function and provide public utility services, companies in the selected sector must have assets. Fixed assets are the basic element that influences the effects of company operations. When utilized in a rational way, they shape an optimum level of production capacities of the company and lower unit costs. High productivity of fixed assets held by a company should be the general goal of management. This elaboration has distinguished the relation between fixed assets and total assets as a measure of effectiveness (with acknowledgment of the specific nature of the sector).

The purpose of rational management in municipal waste management companies must not be only focused on increasing the effectiveness in the economic area, but also in the quality of life of the society, which requires, apart from financial criteria, e.g. ethical or environmental criteria that ensure better and more complete satisfaction of needs of a local community. Rational decisions can be then understood as actions and decisions that acknowledge requirements of high economic effectiveness and increase the quality of life of the society.

This is the context that considerations regarding effectiveness of entities in this sector should be presented. Unfortunately, the lack of replies from companies that received the questionnaire prevented a more complete analysis of the issue.

4.4. The analysis of effectiveness of entities in a municipal waste management system with the application of taxonomic and statistical methods

The assessment of the effectiveness measures for companies that operate in differently organized municipal waste management systems in individual communes utilized a multi-criteria ranking. In order to create a ranking of communes and companies characterized by multiple criteria, the analysis applied a synthetic variable the structure of which was based on the method of zeroed unitarization (MZU). MZU requires several phases. In the first phase, diagnostic variables X_j are divided into stimuli, inhibitors, and neutral variables; next, they are normalized into variables Z_j[102].

For stimuli and inhibitors, the normalization formulae are, respectively, (3) and (4):

$$z_{ij} = \frac{x_{ij} - \min\limits_{i} x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}}, \quad X_j \in S \tag{3}$$

$$z_{ij} = \frac{\max\limits_{i} x_{ij} - x_{ij}}{\max\limits_{i} x_{ij} - \min\limits_{i} x_{ij}}, \quad X_j \in D \tag{4}$$

In the case of the neutral variable, if the range of nominal values $<b_{1j};b_{2j}>$ is known, the normalization formula is as follows:

[102] A. Młodak, *Analiza taksonomiczna w statystyce regionalnej*, Diffin, Warsaw 2006, p. 117; K. Kukuła, *Metoda unitaryzacji zerowanej*, Wydawnictwo PWN, Warsaw 2000, p. 177.

$$z_{ij} = \begin{cases} \dfrac{x_{ij} - \min\limits_{i} x_{ij}}{b_{1j} - \min\limits_{i} x_{ij}}, & x_{ij} < b_{1j} \\ 1, & x_{ij} \in \left[b_{1j}; b_{2j} \right] \ , \ X_j \in N \\ \dfrac{x_{ij} - \max\limits_{i} x_{ij}}{b_{2j} - \max\limits_{i} x_{ij}}, & x_{ij} > b_{2j} \end{cases} \tag{5}$$

The next stage of the MZU involves aggregation of normalized variables, e.g. through arithmetical mean:

$$Q_i = \frac{1}{k} \sum_{j=1}^{k} z_{ij} \tag{6}$$

Values of the Q_i synthetic variable are normalized in the range [0,1] and allow being organized according to the intensity of the analyzed phenomenon. The higher the value of the Q_i variable achieved by an item (closer to 1), the higher the rank it will have in the ranking of analyzed items (and vice versa).

In the area of effectiveness of municipal waste management in communes, 10 properties can be considered as stimuli, 4 properties as inhibitors, and 4 – as neutral variables. Properties in the case of which the higher the value, the higher the effectiveness, included: level of recycling and preparation for re-usage of municipal fractions: paper, metals, glass, and plastics; level of recycling, preparation for re-usage and recovery with other methods for construction and demolition non-hazardous waste which constitutes municipal waste; relation of proceeds from fees for managing municipal waste to the current income of the commune; relation of expenditures of the commune for the municipal waste management system to general expenditures of the commune; amount of waste at the point of selective collection of municipal waste with regard to the number of inhabitants; expenditures for the point of selective collection of municipal waste per capita; expenditures for the municipal waste management system per capita; dynamics of changes of recycling levels with other methods for construction and demolition non-hazardous waste which constitute municipal waste; dynamics of recycling of municipal fractions: paper, metals, glass, and plastics.

The following were qualified as inhibitors (the lower the value, the higher the effectiveness): relation of current expenditures of the commune for the mu-

nicipal waste management system to the amount of commune waste; cost effectiveness of the point of selective collection of municipal waste (expenditures for the point of selective collection of municipal waste/amount of waste at the point of selective collection of municipal waste); two synthetic indicators – (current expenditures of the municipal waste management system/amount of commune waste)/achieved degrees of recycling of fractions of waste: paper, metals, glass, and plastics and (current expenditures of the commune for the municipal waste management system/amount of commune waste)/achieved degrees of recycling with other methods for construction and demolition non-hazardous waste which constitute municipal waste.

Neutral variables (the highest effectiveness, if the values fall within a specific set) included: proceeds from fees for managing municipal waste to expenditures for the municipal waste management system (a distinguished set around 1 – from 0.99 to 1.01); proceeds from fees for managing municipal waste with reference to expenditures for collection and transport of waste (the optimum value of the set falls within the range from 1 to 1.15); the planned cost of the municipal waste management system and expenditures for the municipal waste management system (this is also a range oscillating around 1, yet with higher "marginal values" – from 0.90 to 1.1); the total net profit of companies from a particular commune with regard to expenditures for the municipal waste management system (assuming that the specific nature of public utility services limits the value of profits within a specific range from 0.01 to 0.05). The results of the effectiveness ranking for 23 communes (out of 38 that received the questionnaire) have been presented in Table 34.

According to Table 34, in terms of effectiveness, the best results were achieved by the following communes: Zakopane, Kraków, Olsztyn. The other end of the ranking included: Łódź, Konin i Lublin. Communes that implemented the in-house model are on the 1st and 2nd rank in the ranking and take places from 10 to 14 and 17. By analyzing only the first and the last ranks, it is possible to conclude that communes which apply the said model feature **higher effectiveness** than cities applying the tendering model. In the case of central ranks from 10 to 17, among which 6 out of 8 analyzed communes apply the in-house model, it is justified to conclude that the companies feature **effectiveness that is not lower** than in the case of communes which apply alternative solutions for a municipal waste management system.

Table 34. The ranking of communes according to the level of effectiveness of the municipal waste management system in 2018

Rank in ranking	Value of synthetic variable	Communes
1	0.6217	Zakopane
2	0.5932	Cracow
3	0.5819	Poznań
4	0.5802	Olsztyn
5	0.5611	Opole
6	0.5428	Pruszków
7	0.5401	Gdynia
8	0.5379	Tychy
9	0.5337	Wrocław
10	0.5322	Katowice
11	0.5246	Przemyśl
12	0.5091	Tarnów
13	0.4985	Jelenia Góra
14	0.4803	Wieliczka
15	0.4777	Rzeszów
16	0.4742	Nowy Targ
17	0.4601	Białystok
18	0.4568	Słupsk
19	0.4287	Warsaw
20	0.4131	Nowy Sącz
21	0.4122	Konin
22	0.3873	Lublin
23	0.3569	Łódź

– Communes with a municipal waste management system based on a model other than the in-house model.

– Communes with a municipal waste management system based on a model with a commune company without an in-house tender.

Source: own analysis.

In the area of effectiveness of municipal waste management, 6 companies have characteristics of stimuli, 1 reflects an inhibitor, and 1 – a neutral variable. The group of stimuli included the value of net revenue on sales, yield of equity (return on equity), total execution (rotation) of assets, share of fixed assets in total assets, and the degree of completion of the questionnaire by the company. It means that the higher the value of distinguished indicators, the higher

the effectiveness of the analyzed entity. Inhibitors included the relation between financial costs and total liabilities, while the indebtedness ratio was adopted as the neutral variable in the range (50% - 67% according to the theory of financial management of enterprises).

The outcome of the company ranking has been depicted in Table 35. In the area of financial effectiveness, the best results were achieved by the following companies: Miejskie Przedsiębiorstwo Oczyszczania Sp. z o.o. in Cracow, ALBA S.A., SUEZ Polska Sp. z o.o. The winner of the ranking is the only representative of in-house entities in the first ten ranks of the ranking. The next ten ranks also include only one company from the entrustment model – LECH Sp. z o.o. Other companies operating in that system are ranked in the third, fourth, and fifth ten of the ranking. Thus, it may be concluded that companies that operate in house are not more effective in the financial aspect than other companies. The first rank of Miejskie Przedsiębiorstwo Oczyszczania Sp. z o.o. in Kraków is the proof of skillful financial management of a company conducted by high-class managers.

Table 35. The ranking of municipal waste management companies according to the level of their efficiency in 2018

Rank in ranking	Value of synthetic variable	Company
1	0.5007	Miejskie Przedsiębiorstwo Oczyszczania Sp. z o.o. - Cracow
2	0.4835	ALBA S.A.
3	0.4757	SUEZ Polska Sp. z o.o.
4	0.4348	Suez Zielona Energia Sp. z o.o.
5	0.3989	MPO m.s. w Warszawie Sp. z o.o.
6	0.3762	REMONDIS Szczecin Sp. z o.o.
7	0.3752	Eneris Surowce S.A.
8	0.3741	ENERIS S.A.
9	0.3617	ENERIS EKOLOGICZNE CENTRUM UTYLIZACJI Sp. z o.o.
10	0.3341	Suez Północ Sp. z o.o.
11	0.3237	Zakład Gospodarowania Odpadami Komunalnymi Sp. z o.o. - Olsztyn
12	0.3235	LECH Sp. z o.o.
13	0.3211	KOM-EKO S.A.
14	0.3177	Przedsiębiorstwo Gospodarki Komunalnej Sp. z o.o. - Koszalin
15	0.3159	SIMEKO Sp. z o.o.
16	0.3116	Miejskie Przedsiębiorstwo Gospodarki Komunalnej - Rzeszów Sp. z o.o.
17	0.3094	Zakład Zagospodarowania Odpadów w Poznaniu Sp. z o.o.

18	0.3050	REMONDIS Kraków Sp. z o.o.
19	0.3049	Miejskie Przedsiębiorstwo Oczyszczania Łódź Sp. z o.o.
20	0.3047	Trans-Formers Karpatia Sp. z o.o.
21	0.3020	Przedsiębiorstwo Gospodarki Komunalnej Sp. z o.o. in Słupsk
22	0.2898	Przedsiębiorstwo Usług Komunalnych S.A. - Kalisz
23	0.2861	Przedsiębiorstwo Gospodarki Odpadami Sp. z o.o. - Kielce
24	0.2742	MPGK Katowice Sp. z o.o.
25	0.2712	ALBA Sp. z o.o.
26	0.2717	FCC Polska Sp. z o.o.
27	0.2698	Przemyska Gospodarka Komunalna Sp. z o.o.
28	0.2686	Zakład Utylizacji Sp. z o.o. - Gdańsk
29	0.2684	MPO Białystok Sp. z o.o.
30	0.2623	Przedsiębiorstwo Gospodarki Komunalnej w Suwałkach Sp. z o.o.
31	0.2612	Miejskie Przedsiębiorstwo Gospodarki Komunalnej Sp. z o.o. - Jelenia Góra
32	0.2609	Miejskie Przedsiębiorstwo Gospodarki Komunalnej Sp. z o.o. - Tarnów
33	0.2537	Miejski Zakład Oczyszczania w Pruszkowie Sp. z o.o.
34	0.2532	MASTER-ODPADY I ENERGIA Sp. z o.o.
35	0.2527	PGKiM Sp. z o.o. in Konin
36	0.2503	AVR Sp. z o.o.
37	0.2487	Miejskie Przedsiębiorstwo Oczyszczania Sp. z o.o. in Toruń
38	0.2459	Miejskie Przedsiębiorstwo Oczyszczania Sp. z o.o. Szczecin
39	0.2458	Eko Dolina Łężyce Sp. z o.o.
40	0.2430	BESKID ŻYWIEC Sp. z o.o. Żywiec
41	0.2401	Zakład Komunalny Sp. z o.o. - Opole
42	0.2347	Zakład Gospodarki Komunalnej i Mieszkaniowej w Malborku Sp. z o.o.
43	0.2234	Rejonowe Przedsiębiorstwo Gospodarki Komunalnej - Myślenice
44	0.2208	Zakład Unieszkodliwiania Odpadów Komunalnych Sp. z o.o. - Białystok
45	0.2115	Zakład Utylizacji Odpadów Sp. z o.o. - Myślenice
46	0.2113	Zakład Gospodarki Komunalnej w Wieliczce Sp. z o.o.
47	0.2111	Ekosystem Sp. z o.o.
48	0.2106	Przedsiębiorstwa Usług Komunalnych Sp. z o.o. - Tarnów
49	0.2101	Gdańskie Usługi Komunalne Sp. z o.o.
50	0.2001	Przedsiębiorstwo Gospodarki Odpadami EKOMAZURY Sp. z o.o.
51	0.1922	Zakład Gospodarki i Usług Komunalnych Spółka z o.o. - Lubań
52	0.1799	Inneko Sp. z o.o.

– Company rendering services under a won tender.

– Commune company without an in-house tender.

Source: own analysis.

Here, it should be highlighted that effectiveness measured with the exclusion of missing technical and exploitation data does not constitute a complete assessment of the value of companies in the in-house model.

Spearman's rank correlation coefficient was calculated in order to analyze whether the orderings of companies and communes are compliant, which means that the effectiveness of the commune translates into the effectiveness of companies that operate in such a commune[103]:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}\left(d_x - d_y\right)^2}{n\left(n^2 - 1\right)} \tag{7}$$

where:

d_x, d_y – the ranks of the company in the rankings according to the effectiveness of the commune and own effectiveness,

n – number of companies in the ranking.

The r_s coefficient takes values from -1 to 1 and its positive value stands for ordering compliance of items, while a negative value – for non-compliance (opposite rankings).

In this study, the value of the rank correlation coefficient of 0.099 is the indicator of low ordering compliance of companies and communes at national level and such dependency has no statistical significance (p-value>0.1). Chart 14 has presented the correlation diagram in which points represent companies with their corresponding effectiveness of the commune in which they operate (horizontal axis) and the aggregate effectiveness of own activities (vertical axis).

The line visible in the chart represents the regression function with the following equation: y = 0.1984+0.2207*x. Its positive inclination confirms that higher effectiveness of communes is reflected by higher effectiveness of companies (an increase in aggregate effectiveness of communes by 0.1 will improve, on average, the aggregated effectiveness of companies only by about 0.022), but this dependency has no statistical significance (p-value for the regression coefficient is 0.276).

[103] It only acknowledged companies for which the aggregated effectiveness indicator was calculated and, at the same time, such a ratio was calculated for the commune, in which the company operated.

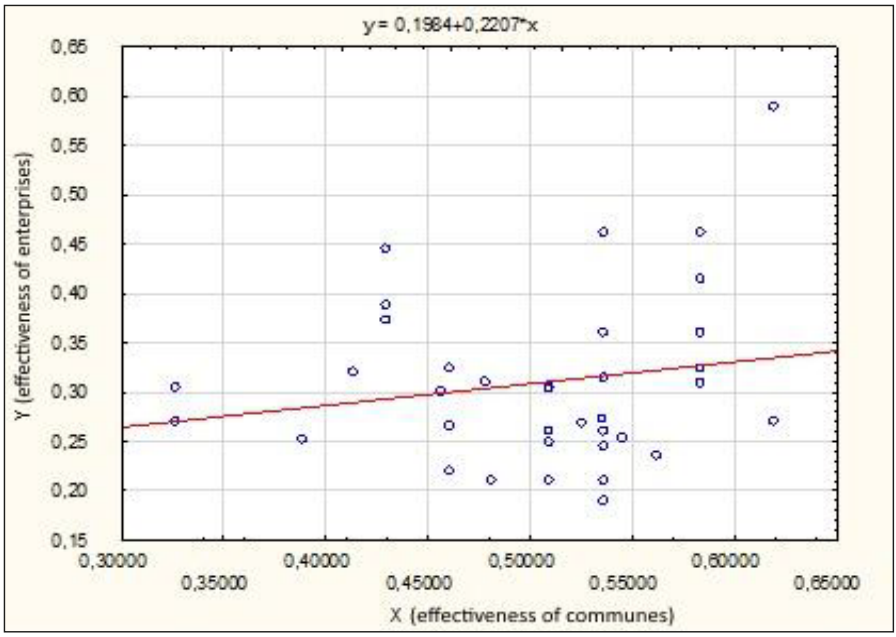

Chart 14. The correlation diagram presenting the relationship between aggregated effectiveness of an enterprise and aggregated effectiveness of communes

Source: own analysis based on Tables 34 and 35.

The above considerations prove that the study on the effectiveness of municipal waste management in communes confirms the advantage of the in-house model. The inability to reflect the said aspect with regard to effectiveness of companies results, above all, from the selection of available data. Since it was impossible to correlate the achieved financial values with other measures, it prevented a thorough analysis of effectiveness of companies. A significant conclusion that resulted from the analysis of company effectiveness is that regardless the organizational and legal form, type of ownership, or the system model that the company operates in, effective management may be achieved through high financial effectiveness.

FINDINGS AND CONCLUSIONS

Municipal waste management – an already recognized field of public utility services and an area of political and economic activity of communes – has been depicted in this monograph in an innovatory[104] manner as a challenge faced by growing urbanization.

In accordance with the formulated theoretical aim of the monograph, the economic, technological and legal grounds of municipal waste management systems have been identified and classified (especially in Chapter 1). Empirical effects of the monograph mainly cover collection of figures and information that supported describing the condition and changes in the municipal waste management system in Poland (2.1) and in deliberately selected Polish cities (Cracow – 2.2; Białystok – 2.3; Koszalin – 2.4; Nowy Targ – 2.5).

The case studies of foreign countries and cities - in the Federal Republic of Germany – Frankfurt am Main and Frankfurt an der Oder (3.1), in the Czech Republic – Prague (3.2), and in the Republic of Austria – Vienna (3.3) – are of an innovatory (unique) character.

The theoretical reflections required classification of knowledge, which posed difficulties due to controversies within the scope of definitions of waste managing and management, various recognition of numerous waste management processes and calculation methods of such crucial standards and norms like level of recycling or recovery, many changes in the act on maintaining cleanliness in communes, the public procurement law and rules for implementation and

[104] The innovatory nature results from the multidisciplinary character of competences, knowledge, and scientific experience of the authors: an economist, an environmental and chemical technology engineer, a construction engineer – consultant and practitioner in the field of municipal waste management.

application of EU directives, including in-house, or the sustainability of projects with the use of public support.

In spite of the complex system of supervision and financial reporting of entrepreneurs and communes or websites on municipal waste management in Poland, direct – source – studies were necessary (R.2 and R.4). Such experience of the authors has been proved in the report by the Supreme Chamber of Control, which has stipulated that: "[…] for half of the inspected communes, data on levels of recycling proved to be unreliable […]"[105].

In the case of foreign companies, the access to data and information is even more difficult and it required knowledge acquired during direct trips to the facilities and learning about the organization and management of municipal waste in cities.

Comparisons between organization and management of municipal waste in the analyzed Polish and foreign cities are problematic in face of diversified statistics and applied measurement methods, e.g. for the achieved levels of recovery and recycling. Polish cities, however, "learn about" the technical, organizational and management solutions used abroad, while the integrated municipal waste management system in Cracow meets numerous the Western standards.

A theoretical analysis and empirical studies allowed confirming the authors' expectations, i.e. that the quality and efficiency of municipal waste management influences the quality of living in a city, yet city management is determined by the integrated and comprehensive nature of municipal waste management. It determines the development of the said economy on the basis of closed circulation. It can be exemplified with the self-governmental model of municipal waste management used in Cracow, where the functioning of all the basic components (facilities) of municipal waste management in the city is maintained. The system is administered by MPO Sp. z o.o. which was entrusted by the commune of Cracow with communal duties of public utility, in the in-house mode, except for the Thermal Waste Conversion Plant that is managed by a communal company – KHK S.A.

The self-governmental model of municipal waste management is also utilized in Białystok, although the structure of the system is more dispersed

[105] Information on inspection results. Implementation of commune tasks within the scope of municipal waste management, Department of Public Administration of the Supreme Chamber of Control, Warsaw, April 2018.

in terms of administration; apart from in-house services, it involves several facilities and entrepreneurs.

Koszalin and Nowy Targ prove that their systems operate without the local government, with the participation of private sector entrepreneurs from outside the commune, which results in lower financial and operational effectiveness. This is reflected by the low rank of the city of Nowy Targ and the fact that Koszalin did not reply to the questionnaire.

In the empirical part, the Authors' intention was to study the sustainability of the fee for municipal waste management to maintain an integrated system of municipal waste management in the commune. It proved impossible since all the said streams are recorded, calculated, and implemented on different grounds – an inconsistent legal regulation, e.g. on maintaining cleanliness and order in communes, on fees for use of the environment, on the act on local government, on tax ordinance law, etc. The identification of the problem and acquisition of remaining data, along with their synthesis, constitute an important result of this monograph and the grounds for further research. It has been determined that the recoverability of fees for municipal waste management in the analyzed cities, according to the provided data, is very high – from 90 to 100%.

An attempt was made to associate the analysis of municipal waste management in communes with operational and financial activities of selected companies – representatives of every commune subjected to the study. They received a specially elaborated questionnaire (Attachment 2). Among others, the questions in the questionnaire referred to: owned facilities, amount of waste accumulated and processed at own waste facilities, effects of recovery and recycling, equipment (garbage trucks), manner of performing tasks in favor of the commune, the number of served real properties, and general financial data. All the information is publicly available and it should be included in reports addressed to the commune and the Marshal's Office. Only two completed questionnaires were received from the companies, including one completed only partially. Financial statements (published in the National Court Register) were used to acquire data that were utilized to assess the financial effectiveness of analyzed companies and the correlation of that effectiveness with selected characteristics of operating effectiveness of communes.

For the analysis, multi-criteria rankings were applied with the use of synthetic variable, the structure of which was based on zeroed unitarization (method of zeroed

unitarization – MZU). Thanks to general financial data, technical and operational data, as well as output data, it was possible to determine rankings of effectiveness: for companies in the system of municipal waste management, communes.

A correlation diagram was created – the dependency between the aggregated effectiveness of companies and the aggregated effectiveness of waste management in communes.

Being aware of the difficult obstacles regarding acquisition of reliable data and the complex technical and technological dependency of municipal waste management in communes on financial management of companies – the majority of commercial companies (obligated to gain earnings through generation of profits) – we draw the final conclusion: communes which entrust municipal companies with management of an integrated system for municipal waste management or/and its individual chains feature more more properties of operating, economic and financial effectiveness within the scope of management of municipal waste.

The theoretical and the empirical analysis encourage continuation of the research over the organization and administration of municipal waste management. Such a demand has also been indicated in the above-mentioned report of the Supreme Chamber of Control, which concludes that: "there is a risk that Poland might not achieve, by 2020, the recycling level of 50% imposed on by the EU regulations, which indicates a need for more intensified actions at all levels, from communes, through region, up to the Ministry of the Environment, in order to increase the achieved levels of recycling […]". This monograph proves that such threats can be mitigated by adding rights and obligations to the duties of city authorities; their current regional (municipal and inter-municipal) character does not ensure meeting the standards and goals imposed on management of municipal waste.

Furthermore, the Resolution adopted by the General Assembly on 25 September 2015, among 17 development goals by 2030, defined one of them as follows: *To make cities and human settlements safe, stable, balanced, and favoring social inclusion*. The actions to achieve the above goal involved the following: *By 2030, decrease the per capita ratio of unfavorable impact of cities on the environment, paying particular attention to the quality of air and management of municipal waste and other types of waste.* This monograph constitutes a humble contribution to the knowledge that is necessary to fulfill that mission.

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ATTACHMENTS

Attachment 1. Questionnaire regarding municipal waste management in the commune

QUESTIONNAIRE

Pursuant to Art. 8 of the Act dated 3 October 2008 on publishing information about the environment and its protection, public participation in the environmental protection and environmental impact assessment (Polish Journal of Laws 2016 item 353), we would like to ask you to provide answers to the questions included in the questionnaire.

Municipal waste management in the commune

Commune:		
The municipal waste management system in the analyzed period (2012-2018):	Please mark with X and briefly describe	
Model with a commune company without an in-house tender		
Model with a commune company selected through a tender		
Model with a private entrepreneur		
Combined model		
Waste collection method	Please describe briefly	
Current method of selective collection of municipal waste		
When will the system involving collection of municipal waste by 5 fractions be implemented		

Supplementary information:	2012	2014	2016	2017	2018
Commune inhabitants					
Commune area					
Number of statements filed in the commune	X				
Number of sectors in the commune	X				
Amount of municipal waste collected in the commune (in total) in Mg	2012	2014	2016	2017	2018
Amount of produced and processed municipal wasted at own facilities in Mg:	2012	2014	2016	2017	2018
PSZOK (point of selective collection of municipal waste)					
MBP (mechanical and biological processing of mixed municipal waste)					
Stabilized compost					
Sorting plant – raw material waste					
Composting plant					
ITPOK (thermal municipal waste conversion plant)					
Landfill sites					
Financial information	Please describe briefly and provide a link to resolutions				
Manner (method) for determination of the fee for municipal waste management (copy of the resolution by the municipal council)					
Rates of fees for municipal waste management (copy of the resolution by the municipal council)					
Financial data in PLN	2012	2014	2016	2017	2018
Commune budget income on fees for municipal waste management – fees assigned by statements					
Amount of cash proceeds to the commune budget on fees for municipal waste management					
Amount of cash proceeds from participation of the commune in fees for the use of the environment in a portion regarding fees for placement of municipal waste at a landfill site (section 90019).					
Total current income of the commune (without funds from foreign sources)					

Current expenditures of the commune for an integrated municipal waste management system (in 2012, for municipal waste management)					
Current expenditures of the commune for collection, transport, gathering, recycling and disposal of municipal waste					
Current expenditures of the commune for creating and maintaining points of selective collection of municipal waste					
Current expenditures of the commune for the administrative handling of the system					
Current expenditures of the commune for education in proper handling of municipal waste					
Current expenditures of the commune for removal of municipal waste from places not intended for storing and depositing them					
Current expenditures of the commune for other actions as a part of the system (specify)					
Current expenditures of the commune for municipal economy					
Total current expenditures of the commune					
Estimate of costs of the municipal waste management system in the commune					

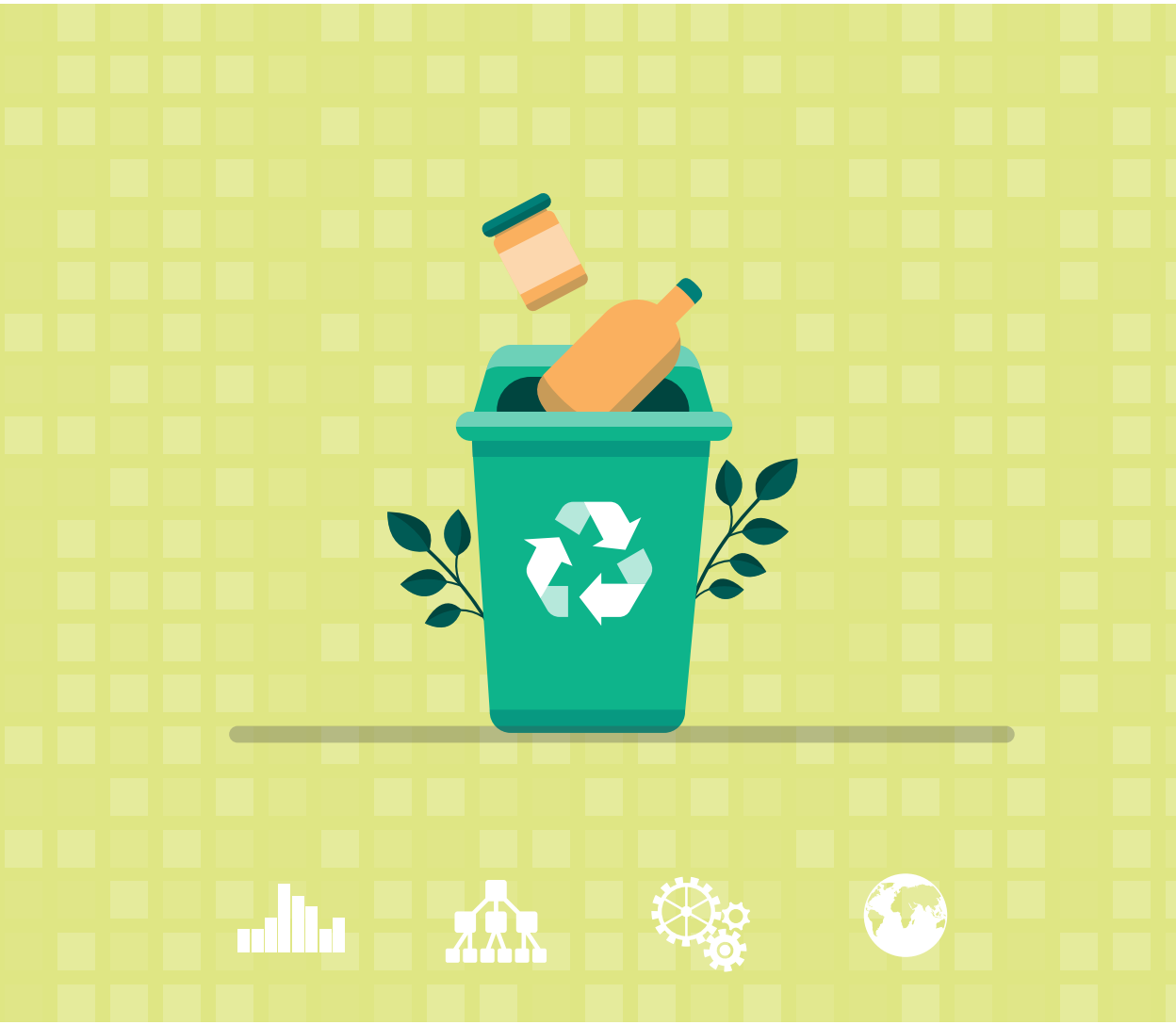
Attachment 2. Questionnaire regarding municipal waste management at the company

QUESTIONNAIRE

Municipal waste management at the company

Company name:					
Owned facilities in 2017:	If yes, please mark with X and describe				
MBP (mechanical and biological processing of mixed municipal waste)					
Sorting plant					
Composting plant					
ITPOK (thermal municipal waste conversion plant)					
Landfill sites (if it uses an external one, specify the place)					
Large-size waste grinding plant					
Dismantling of electrical devices					
Amount [Mg]	2012	2014	2016	2017	2018
Collected waste (in total)					
Mixed					
Collected selectively					
Kitchen waste					
Green					
Large-size					
Used electrical and electronic equipment					
Hazardous					
Clothes					
Sent to thermal processing					
Sent to landfill sites, including stabilized compost					
Effect of waste processing at own facilities [%]:	2012	2014	2016	2017	2018
Level of recycling and preparation to reuse municipal fractions: paper, metals, glass and plastic					
Limitation of the weight of municipal waste subject to biodegradation handed over to a landfill site					
Level of recycling, preparation to reuse and recycle with other methods for construction and demolition waste being non-hazardous municipal waste					

Amount of effect/product from processing [Mg]:		2012	2014	2016	2017	2018
Paper						
Metal						
Plastic						
Glass						
Other information:		2012	2014	2016	2017	2018
Number of garbage trucks						
Collection frequency	selective					
	mixed					
	green					
	glass					
Number of served properties						
Collection efficiency (amount of collected waste [Mg/d])						
Additional activity in 2017:		If yes, please mark with X and describe				
Street cleaning						
Snow removal						
Other						
Method of performance of tasks in the analyzed period		If yes, please mark with X and describe				
- Independently						
- As part of a consortium						
Number of served		2012	2014	2016	2017	2018
Real properties						
Inhabitants (single-family development)						
Inhabitants (multi-family development)						
Business undertakings (business)						
Financial data in PLN:		2012	2014	2016	2017	2018
Estimate of revenue on sales of municipal waste management services						
Estimate of own costs of municipal waste management						
Estimate of investments for waste management processes and installations incurred by the entrepreneur						



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