7

DETERMINANTS OF MUNICIPAL WASTE MANAGEMENT SYSTEM BASED ON THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT

7.1 INTRODUCTION

Implementation of the conception of sustainable development in frames of waste management system and monitoring the effects of conducting such activities is connected with designing the proper measurement tools. The role of measures in this context not only enables designing a current state of the system but also allows comparing the systems and indicating the processes that require improvement. A practical use of these tools is the basis of assessment of the current state of economy as well as verifies the plans and prognosis concerning the social, ecological and economic aspects.

An integrated system of waste management requires a complex and multi-criteria approach during the measurement of sustainable development of the regional systems. Consequently, the base of indicators and corresponding measures adequately elaborated makes it possible to conduct a reliable assessment of processes and their effectiveness.

A correct design of the local models of waste management based on the unified standards and measures of sustainable development will allow creating a strong system of waste management, which thanks to synergy effects will enable objectives achievement of climate and energy package [10].

7.2 MODELLING ASSUMPTIONS

Modeling of the systems is a tool serving for simulation of the particular solutions. A properly designed model may also constitute a rich information source as well as indicate weaknesses of the system. Considering complexity of the topic, there is a general scheme of system modeling adopted.

The scheme presented (Fig. 7.1) should indicate the need for continuous system improvement on the basis of the weaknesses identified that are the results of analysis of the previously prepared indicators. In effect, the system witness points are of great importance regarding quality control. Designing the model is an obligatory activity as its outcome allows a reliable analysis of the reality with a division into the key objects and processes and also with determination of system boundaries. Cataloguing

the current state of economy is a basis for the analysis and creation of system optimization models, which, due to criteria and conditions adopted, will make it possible to implement the development activities and proceed with their validation. Standardization of procedures may increasingly simplify the system measurement processes due to their effectiveness and functionality and also evaluate their compliance with the principles of sustainable development. An effective use of the resources possessed, achievement of the planned levels of recovery and recycling, application of the best BAT techniques that are accessible as well as minimization of a negative influence on the environment are one of many activities and objectives [7] which have to be faced by each local system. Unification of procedures that realize the same economic, environmental and social objectives should be favorable too and at the same time would enable an effective assessment of the activities conducted.

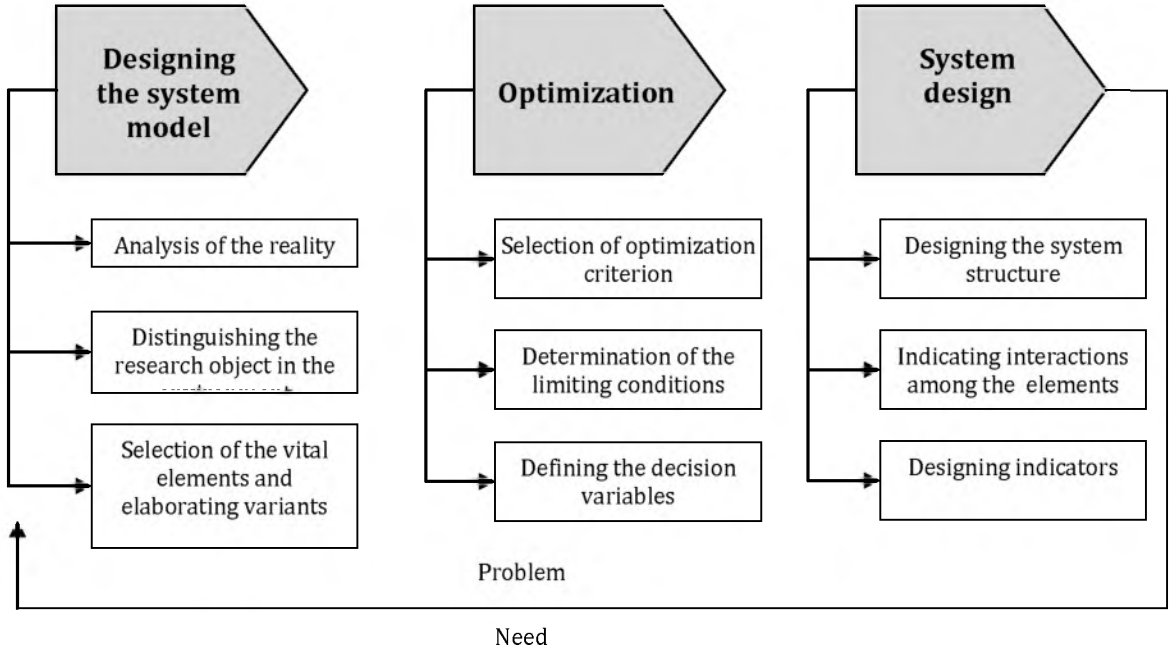

Fig. 7.1 A general scheme of system design process

Source: own work based on [5]

Depending on the particular objective of the analysis, the degree of modeling the reality does not always have to include all the elements. The processes and its boundaries correctly distinguished are a basis for all possible research on models, therefore their proper identification determines the usability of analyses. Consequently, it may be assumed that when constructing the model we copy the details of reality that bring the most precise and concrete information and examination itself enables a detailed analysis as much as it is needed in the particular place and time. In connection with the above, various models are often adopted in the way that helps to distinguish the most important information without involving the elements that have a previously defined objective from the point of view of research.

When trying to systematize the most important stages of model construction the following activities should be included [5]:

- analyze the needs and objective of system modeling,
- identify the object of modeling,
- determine boundaries of the analysis and at the same time model conditions and limitations,
- choose system elements that will be a basis for research and analyses,
- determine the interaction between the model features,
- verify correctness of the model designed,
- test the model,
- accept the model.

The aforementioned points are the main activities that each designer should do. The level of their particularization as well as possible variants extending the range of the analysis only depend on the person responsible for designing and on the level of the scale of works. What is important, the aforementioned activities cannot be treated independently. The results of each one constitutes a reference point for other activities which, due to their specificity, may become a decision element and in case of inconsistencies – induce a return to the previous stages and their repeated verification. The modeling process is an iterative process and in its result the created algorithm of conduct should include such activities the choice of which will enable making a loop. Therefore, it may be stated that in all cases the process of system design – deciding about its architecture, should realize all the requirements, objectives and include the limitations that were ascribed to the previous modeling phases.

It would be a truism to say that in order to design the system model properly it is necessary to obtain knowledge about its characteristic features and specificity. The database previously built concerning the system and its environment is a basis for problem recognition as well as for selecting the most important information from the point of view of research conducted. Ordering information is not an easy task. When building the model one should pay attention to data accessibility, measurement possibilities and their standardization. The quantitative values are necessary when making model description and verification of the solutions available. Identification of the decision problem is connected with determining the following values [5]:

- parameters – unchangeable values, previously known or a priori indicated, being a basis for calculation during resolving the problem itself,
- decision variables – the variables that need to have their value determined and that are the goal of resolving a particular research problem,
- limitations – expressed in a form of system of equations, expressions that include the decision variables previously determined,
- criterion function – also called as objective function or quality indicator that ascribes the searched values of decision variables to the solution.

7.3 VITAL FACTORS OF SUSTAINABLE DEVELOPMENT

A complex analysis of the integrated system of waste management is not an easy task in the view of sustainable development. A range of criteria and conditions

that should be included in the indicators designed are aimed at facilitating the assessment of developed phenomena and their result should be easy to interpret and justify scientifically. Proper data quality and regular measures updating in terms of compliance with the law is a key issue in frames of practical application of these tools.

During literature cataloguing one may encounter various attempts of elaborating the sustainable development indicators. Considering the division of sustainable development conceptions into three basic aspects, the division of the indicators selected was also designed according to the social, economic and ecological area [11].

Social assessment indicators

The social aspect constitutes an integral part of sustainable development philosophy, expressing at the same time the citizens' business as a foundation of law and waste management system elaborated. Taking into account all citizens' rights and obligations, the need for activities integration is suggested that would include both environment protection as well as active participation in frames of the activities undertaken. The prior aspects of pro-social actions, according to sustainable development, are compliant with three main perspectives that are graphically presented in Figure 7.2.

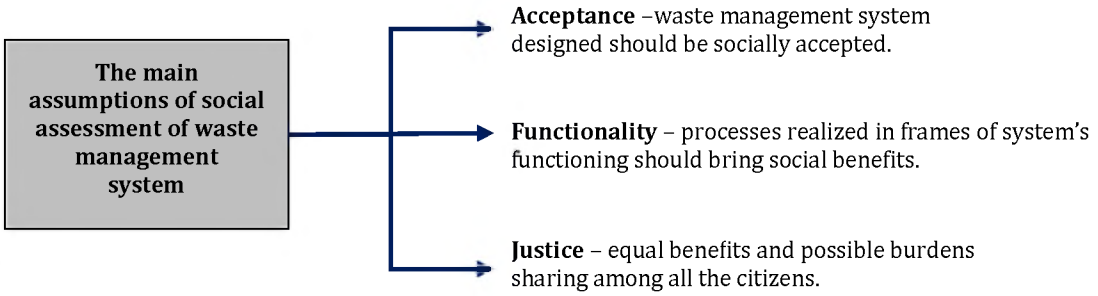

Fig. 7.2 The main assumptions of social assessment

Source: own work based on [2]

Waste collection, transport and processing belong to subsystems that affect the society the most and at the same time are subject to a detailed analysis. All the burdens connected with the processes undertaken in frames of waste management are of direct influence on all the residents, therefore the tasks are important that are supposed to minimize this negative influence. Controlling these phenomena is possible thanks to such indicators as, among others [2]:

- indicator that quantitatively expresses dour nuisance that is produced during waste collection/transport/processing in a particular municipality;
- indicator of subsystem's convenience of functioning, being an equivalent of residents' convenience, proximity of waste bins from the place of residence has a great influence on this indicator;
- indicator of urban land development which includes the share of infrastructure connected with functioning of waste management system in the total area of particular municipality;
- indicator of noise level – calculated for each subsystem;

- indicator of traffic intensity that present the share of using the transporting network and increase in traffic level when using infrastructure in frames of waste management system's functioning;
- employment quality in system's subsystems – including a total number of workplaces in waste management.

The aforementioned ratios are only a part of complex system assessment concerning each examined social aspect. The values being a result of application of various formulas constitute a basis for analyses in case of research and comparisons of waste management subsystems.

Economic assessment indicators

An economic aspect of the sustainable development is tied to a specific technical and organizational system which is examined in the determined time horizon. Separation of the boundaries of the system, in order to subject to analysis the most important costs and income related to the functioning of the system, is also significant from the point of view of research. A group of priorities that constitute the grounds of the defined indicators for the analyses is also assigned to economic assessment. Their graphic presentation is included in Figure 7.3.

Fig. 7.3 The main assumptions of economic assessment

Source: own work based on [2]

In case of economic analyses of the private economic subjects – the greatest attention is paid to economic indicators. Balancing income and expenditures, and therefore determining the financial possibilities, is a basis for planning further investments and improvement of the system. The economic aspect can be assessed by the use of, among others, such indicators as:

- indicator of the total annual cost of waste management subsystem per one household (per capita),
- indicator of the total annual cost of waste management system per one household (per capita),
- indicator calculated based on income from recovery and recycling,
- indicator of the cost of waste management, calculated in relation to the GDP of the municipality,
- indicator of subsidies/grants calculated per capita.

Within the studies concerning the economic aspect of the activity of the system, some areas can be shown that are a basis for the proper actions increasing income of the municipality or making possible to decrease its costs. One should remember that 'the best does not mean the cheapest', therefore, in case of sustainable development accepting this aspect as the main one is unacceptable. The weights ascribed to all the areas of research are at one level, thus the suggested improvement actions are a resultant of it.

Environmental assessment indicators

Environmental assessment conducted as a part of activities for sustainable development is a highly complex analysis that may utilize many methods and tools. In order to systematize the main directions of environmental research, a scheme illustrating the areas and objectives of the analyses was prepared: (Fig. 7.4).

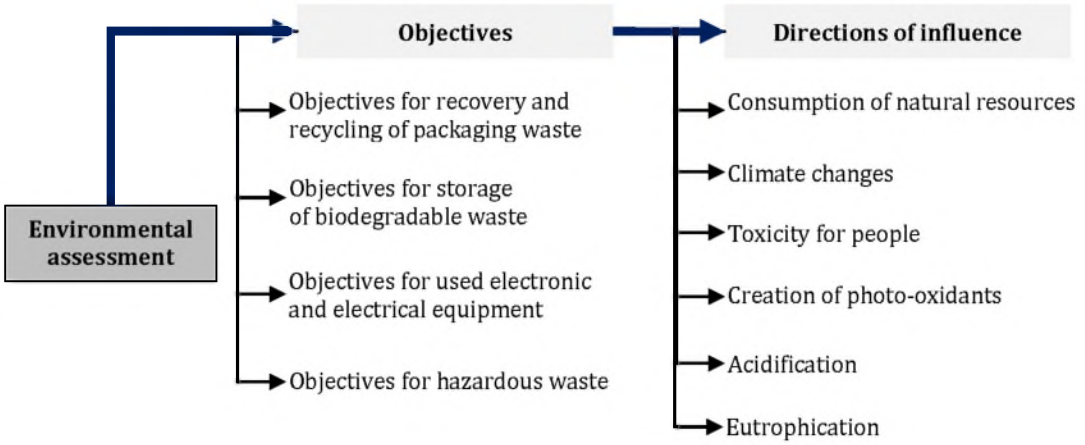

Fig. 7.4 The components of environmental assessment

Source: own work based on [2]

One should also note the general principles of dealing with waste [3], which are a basis for planning of municipal waste management on both state and municipal levels, among them we include:

- the principle of prevention – action related to minimizing the amount of the generated waste in order to protect the natural environment,
- the precautionary principle – actions need to be taken that are aimed at reducing the negative influence of waste (especially of hazardous waste) on the health of people and on the natural environment,
- the principle of proximity and self-sufficiency – the units responsible for creating the system should organize its realization in such a way, as to take into consideration the localization of the installations of waste processing.

Among the general principles of dealing with waste we also include the following principles: the polluter pays and the extended responsibility of the producer. Those principles refer mainly to industrial waste, which is not a subject for these considerations.

The hierarchy of dealing with waste, not mentioned before, constitutes a basis for any actions related to waste management, treats the principle of prevention, which is the most desired action, as the priority. The actions taken in case of the examined areas and their compliance with the hierarchy are the subject of the qualitative analysis of the system, while in the quantitative assessment the following indicators, among others, may be taken into account [2]:

- indicator of the climate change, which examines the influence of anthropogenic emission on the radiative properties of the atmosphere, including absorption of thermal radiation;
- indicator of toxicity for the human health – taking into consideration the level of influence of harmful substances emitted into the environment;
- indicator of photo-oxidants – which concerns the creation of active chemical compounds such as ozone, as a result of the influence of solar radiation on some of the primary types of air pollution;
- indicator of acidification – related to the negative influence of the soil, ground and surface water;
- indicator of eutrophication – determining all influences of fertilizer substances, including the most important ones – nitrogen and phosphorus, which contribute to adverse changes in the natural environment;
- indicator of the level of recovery and recycling of packaging waste – calculated as the sum of particular packages leaving the sorting and MBP plants as well as the plants for thermal waste processing;
- indicator of restricting the amount of storage of biodegradable waste – calculated in relation to the number of biodegradable waste in the year 1995 [4].

The results achieved thanks to the use of chosen indicators enable designing an intervention field, at the same time being a stimulus for more detailed analyses. A correctly presented model should be an image of the implemented changes and also should simulate the effects of the implemented actions [6]. The choice of the best solution is not an easy task – all of the designed variants characterize different strategies and are the results of individual approach to the weights of the chosen indicators.

7.4 ASSUMPTIONS FOR DESIGNING THE INDICATORS OF WASTE MANAGEMENT SYSTEM – THE RESULTS OF AUTHORS' RESEARCH

As a part of the pictorial presentation of the topic of the paper, the main guidelines for creating the measurement indicators of the model of waste management system were created.

The analysis of the current state of waste management, the basis for which the information was taken from the data of GUS (Central Statistical Office) [8] and the National Waste Management Plan 2014 [7], made it possible to prepare the following summaries.

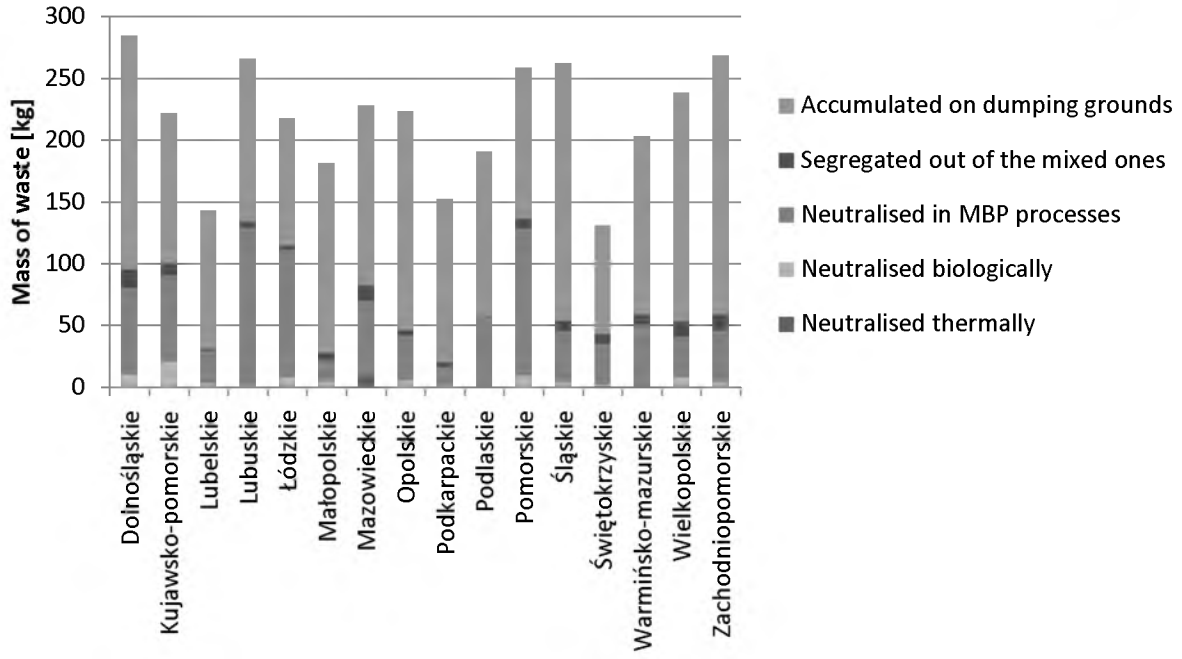

Fig. 7.5 The share of waste disposal per capita divided by provinces

Source: own work based on [8]

One of the main areas for analyses of waste management system is the level of disposal. Indicators (Fig. 7.5), prepared in such way allow illustrating the share of appropriate practice with collected waste per capita in the examined region. In the year 2012, on average, 68% of waste was deposited in landfills – these negative results present the scale of the problem with incorrect waste management in each province.

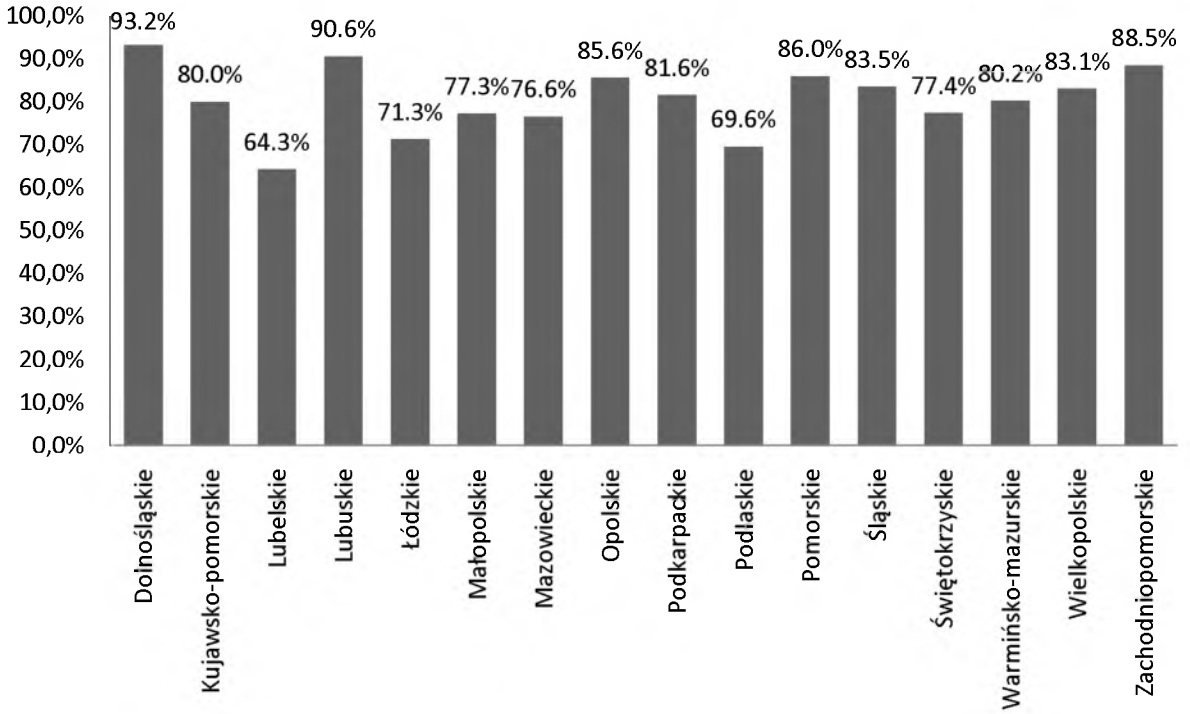

Fig. 7.6 The share of residents included in the collection of waste divided by provinces

Source: own work based on [8]

The share of residents in the system of waste collection is another significant indicator. The expected value which each municipality should strive to reach is 100% - such a result would mean participation of all the residents in waste management system. The reality however, often verifies the objectives and expectations – the calculated share for the year 2012 in each of the provinces is presented on a chart (Fig. 7.6). These results show the need for taking immediate actions, increasing involvement of the residents which should minimize the uncontrolled handling of waste by the people who are not included in the system.

The economic aspect may be verified thanks to the use of the indicator of the share of ecological funds in the total sum of funds allocated to waste management (Fig. 7.7). The correctly designed data are a valuable piece of information for those deciding about the possibilities of increasing the share of additional, external funds as a part of financing new actions – and therefore they make benchmarking possible in the area of ways of funding the pro-ecological undertakings.

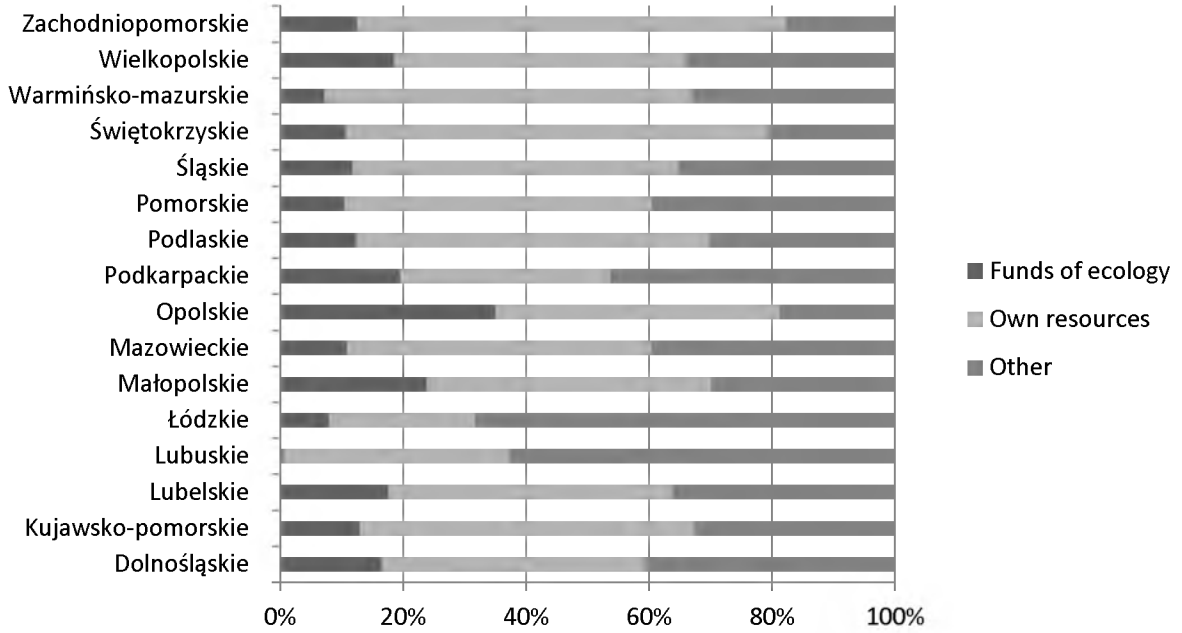

Fig. 7.7 The share of means of financing waste management

Source: own work based on [8]

Valuable information, in the view of the research object and analyses, may also be acquired by confronting the values of the indicators on the field of Europe. In this study, the example of greenhouse gas emissions has been brought up (Fig. 7.8) which also may be taken into consideration during the course of the analyses of the current situation against the background of the European average. This data is extremely significant during the works on further legislative changes, which are supposed to use good practices of the best management systems and implement those actions which will enable meeting all the EU requirements.

The values of the included variables presented above are an entry point for making the creation of the model, based on which improvement of the system will be possible. The diametric differences between the received and expected value are a signal for

taking actions explaining this negative phenomenon. The causes can be in statistical errors that often deviate from reality or they can actually show the weak points of the system. The historical data, which may illustrate the trend of changes and predict the future amounts is also significant from the point of view of research. Such analysis enables a more detailed approach to the topic and at the same time allows identification of those areas that require improvement actions.

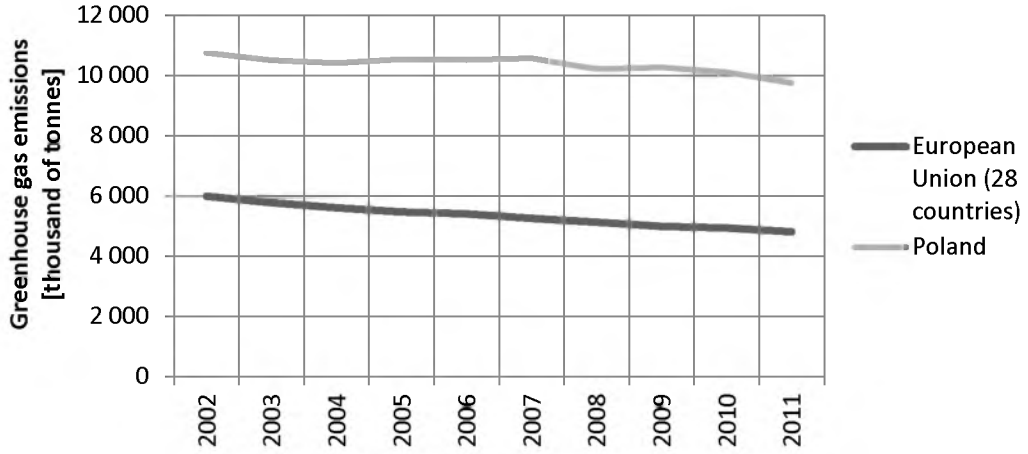

Fig. 7.8 The emission of greenhouse gases in Poland and in the EU

Source: own work based on [12]

CONCLUSIONS

During the works on the attempt to model the waste management system, there were key areas of activities observed that were the grounds for elaborating the assumptions. Literature cataloguing and own research were the basis to create an image of waste management system with indication of the important needs in the view of the analysis. The aspects of sustainable development determine the most important system features, therefore their proper and regular monitoring should be a vital element of the process of effectiveness assessment.

In case of building the system based on the domestic and European regulations, special attention should be paid to monitoring and control of the basic rules connected with the correct organization of waste management, including:

- providing the planned recycling level of biodegradable waste, planned level of energy recovery,
- fulfilling technical and organizational requirements imposed by the law in force,
- organizing a selective collection of segregated and non-segregated waste,
- encompassing 100% residents of the analyzed area concerning collection,
- organizing a proper functioning of the Point of Selected Municipal Waste Collection,
- providing adequate infrastructure that enables correct waste gathering and collection (bags, bins, containers),
- waste collection optimization with assumptions of sustainable development philosophy,

- selection of the best municipal waste recovery and neutralization techniques,
- extending residents' education how to make a correct municipal waste collection,
- quality control of the research conducted.

Thanks to listing the information above it is possible to conduct the effectiveness assessment of waste management system along with ecological, economic and social aspects of its functioning that are an effect of the results and weights adopted for the particular indicators. It may be a basis for system monitoring and all possible repair actions that are aimed at improvement of the weaknesses. Designing a set of indicators for waste management in frames of sustainable development conception may bring many benefits, for example:

- development control in frames of designed policy, strategy, objectives,
- making reliable comparisons between the subsystems or local and European systems,
- database ordering that concerns the most important information about, among other, environment, waste flow and costs of system's functioning,
- providing vital information that enable communication among all the system participants,
- designing important development factors and facilitating operational planning.

Integrated and rational approach to system organization requires standardization from the managers which would allow a correct analysis and assessment of all the subsystems along with the activities subordinated – consequently, it is necessary to conduct a proper system modeling with the inclusion of all the possible processes and determination of the assessment indicators. For this purpose it may become essential to create a coherent list of indicators enabling preparation of a clear reporting system of data directed to, among others, realization of 20/20/20 objective, what allows notification of the level of obligations' fulfillment that result from climate and energy package.

REFERENCES

1 Alankiewicz T.: Prac doktorska, Skuteczność funkcjonowania gospodarki odpadami na przykładzie jednostek samorządowych województwa wielkopolskiego, Poznań 2009.

2 Boer E., Boer J., Jager J.: Planowanie i optymalizacja gospodarki odpadami. Podręcznik prognozowania ilości i jakości odpadów komunalnych oraz oceny zgodności systemów gospodarki odpadami z zasadami zrównoważonego rozwoju, Wydawnictwo PZiTS, Wrocław 2005 r.

3 Dyrektywa Parlamentu Europejskiego i Rady 2008/98/WE z dnia 19 listopada 2008r. w sprawie odpadów oraz uchylającej niektóre dyrektywy (Dz. U. L 312 z 22.11.2008r.).

4 Dyrektywa Rady 1999/31/WE z dnia 26 kwietnia 1991r. w sprawie składowania odpadów (Dz. U UE 182 z 16.7.1999r., z późn. zm., str. 1).

5 Gaska K.: Modelowanie zintegrowanych systemów gospodarki odpadami z wykorzystaniem metodologii zorientowanej obiektowo, Wydawnictwo Politechniki Śląskiej, Gliwice 2012.

6 Jąderko K., Białecka B.: Wybrane problemy budowy systemu gospodarki odpadami komunalnymi w świetle nowych przepisów. [in:] Biały W., Kuboszek A. (ed.): Systemy wspomagania w Inżynierii Produkcji. Środowisko i bezpieczeństwo w Inżynierii Produkcji, Gliwice 2013, pp.135-145.

7 Krajowy plan gospodarki odpadami 2014, (M.P. Nr 101, poz. 1183).

8 Ochrona środowiska, Główny Urząd Statystyczny, Warszawa 2013.

9 Plan Gospodarki Odpadami dla Województwa Śląskiego.

10 Szyjko T. C.: Odzysk energii z odpadów komunalnych. Wyzwania dla Polski, Energia Gigawat – nr 1/2013.

11 Walery M., Podwójci P., Biedugnis S.: Wpływ wybranych parametrów wejściowych systemu gospodarki odpadami medycznymi na koszt jego funkcjonowania i strukturę, Rocznik Ochrona Środowiska 2009, Tom 11, pp. 1329-1340.

12 http://epp.eurostat.ec.europa.eu/portal/page/portal/environment/data/database [16/04/2014].

DETERMINANTS OF MUNICIPAL WASTE MANAGEMENT SYSTEM BASED ON THE PRINCIPLES OF SUSTAINABLE DEVELOPMENT

Abstract: *Creating an indicator that monitors sustainable development is one of the most difficult methodological and implementable tasks in waste management system. A need for unification and standardization of control procedures is a stimulus for system modeling. Its objective will be to create a set of indicators for waste management.*

In the paper there is an authors' attempt presented concerning distinguishing the key areas of waste management system that enable application of indicator mechanism. The problems of using the chosen indicators were examined for the particular province systems of municipal waste management, allowing at the same time comparisons and distinguishing the key problems in the analyzed areas.

Key words: *Sustainable development indicators, sustainable development, waste management system*

DETERMINANTY SYSTEMU GOSPODARKI ODPADAMI KOMUNALNYMI OPARTEGO O ZASADY ZRÓWNOWAŻONEGO ROZWOJU

Streszczenie: *Tworzenie wskaźnikowego monitoringu zrównoważonego rozwoju to jeden z trudniejszych zadań metodycznych i implementacyjnych w zarządzaniu systemem gospodarki odpadami. Potrzeba ujednolicenia i standaryzacji procedur kontroli jest bodźcem do modelowania systemu, którego celem będzie stworzenie zestawu wskaźników gospodarki odpadami.*

W artykule przestawiono autorską próbę wyodrębnienia kluczowych obszarów systemu gospodarki odpadami w ramach których możliwa jest aplikacja mechanizmu wskaźnikowego. Problematyka wykorzystania wybranych wskaźników została opracowana dla danych wojewódzkich systemów gospodarki odpadami komunalnymi, umożliwiając tym samym porównanie i wyodrębnienie kluczowych problemów w analizowanych obszarach.

Słowa kluczowe: *Wskaźniki zrównoważonego rozwoju, zrównoważony rozwój, system gospodarki odpadami*

mgr inż. Karolina JĄDERKO, prof. dr hab. inż. Barbara BIAŁECKA
Silesian University of Technology
Faculty of Organization and Management
Institute of Production Engineering
ul. Roosevelta 26, 41-800 Zabrze, Poland
e-mail: Karolina.Jaderko@polsl.pl; Barbara.Bialecka@polsl.pl