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# Innovative and intelligent solutions for recycling of household waste in Bulgaria

Krasimira Dimitrova[1]

1-Technical University of Varna, Department of Industrial Management, 9010, 1 Studentska Street, Varna, Bulgaria

Corresponding author contact: krasimira.dimitrova@tu-varna.bg

***Abstract.*** Waste from industrial and other human activities, as well as household waste is a major source of environmental pollution. If it is controlled and managed in an adequate and intelligent way, the waste can be a valuable source of raw materials, especially considering that many of them are becoming more and scarcer. Many countries still manage their waste by landfills, although they are not sustainable in the long run. Landfill sites are potential pollutants of soil, water and air. The uncontrolled waste disposal can cause the release of chemicals that pose a danger to the human life and health. Among other things, the valuable materials in waste are lost. It is impossible to stop waste generation and the only alternative is their reuse through recycling and innovative utilization. Good waste management can greatly contribute to economic growth and work places creation. It saves valuable resources, helps to avoid expensive cleaning activities, as well as to prevent health and environmental problems. This study aims to analyze the situation of waste treatment in Bulgaria and to search for innovative intelligent solutions, based on international experience and best practices.

**Keywords:** waste, recycling, composting, environmental problems, system of underground bins

## 1 Introduction

Environment is constantly changing. And increasingly visible and tangible are the issues that surround it. Natural disasters, abnormal periods of warming and cooling, threatened animal and plant species, deforestation and depopulation of large areas of the planet, different types of weather patterns and much more - these are just some of the environmental problems facing mankind. Global warming is now an indisputable fact that our planet is warming and we humans are definitely part of the problem. All over the world people are facing many new and challenging environmental problems every day. Some of them are small and affect only certain ecosystems, but others dramatically change the nature and the environment.

Our planet is on the brink of a severe ecological crisis. Current environmental problems make us vulnerable to disasters and tragedies now and in the future. We urgently need to deal with environmental problems that are all around us. The main environmental problems require an urgent decision. Most actual of them are: Pollution; Global Warming; Overpopulation; Natural Resource Depletion; Waste Disposal; Climate Change; Loss of Biodiversity; Deforestation; Ocean Acidification; Ozone Layer Depletion; Acid Rain; Water Pollution; Urban Sprawl; Public Health Issues; Genetic Engineering.

Waste from the activity and life are one of those problems. Only people can generate waste. In nature there is no waste. The waste created by a natural process or organism quickly become resource used by other processes and organisms. In nature, everything is recycled, production and utilization are well balanced and nutrient cycles continuously maintain subsequent cycles of production. This is the so-called circle of life and a clear strategy related to ensuring stability and resilience of natural systems. But there are artificial systems, which is an important economic value of materials and energiyal and where production and consumption are the dominant economic activities. These systems have a highly destructive impact on the environment, since they require massive consumption of natural resources and energy and return the finished product (waste) into the environment in a way that it causes irreversible damage. The presence of waste is an indication of overconsumption and materials that are not used efficiently. The capacity of the environment to absorb and process these materials is

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also insufficient. Valuable resources in the form of matter and energy is lost. The main problem is the sheer volume of waste produced and dealing with it. (Cheremisinoff 2003).

Most efforts to manage waste today are focused at local government level and based on high technology, but waste disposal is associated with high energy consumption. The predominant methods are still landfilling and incineration. These methods are becoming more expensive and energy inefficient. The financial cost of managing the long-term effects of the disposal of waste in the environment are extremely large. Make and cost of clearing the environmental impact on habitats, wildlife and biodiversity. This suggests that waste disposal is not sustainable and have negative consequences for future generations. The efforts to waste management should be aimed at minimizing waste, as well as processing and recycling. World practice shows that efforts should be focused on urban and industrial areas, as well as to individuals starting at the household level through recycling, energy efficiency and environmentally friendly technologies such as composting, gray water systems, biogas solar energy and heating systems etc. (Sunil 2011a), (Sunil 2011b).

Organic waste is handled easily in small and medium-scale to industrial composting. Organic waste is handled easily in domestic and medium to industrial scale composting. Composting significantly improves fertility and health of our territory, and will become increasingly important resources to ensure our food security by reducing dependence on inorganic fertilizers made from fossil fuels.

Treatment of the solid waste is most often associated with the implementation of an integrated system for the efficient management and utilization of energy potential. It includes collection, sorting, recovery, treatment and recycling of waste by landfilling, recycling, biological treatment, thermal treatment and the like.

According to statistics for 2014, 44% of municipal waste in the EU are recycled or composted to 31% in 2004. By 2020, EU countries must recycle or compost over 50% of waste. According to the new the requirements until 2030 at least 70% by weight of household waste (those from households and small businesses) must be recycled or prepared for recycling (i.e. inspected, cleaned or repaired). For packaging materials such as paper and cardboard, plastic, glass, metal and wood is provided the share of recycling to reach 80% in 2030, with intermediate targets for 2025. It is provided limitation to 10% share of landfilling of municipal trash until 2030. EU also offers this share be reduced to 5%, although the extension to five years under certain conditions for those member states in 2013. They landfilled more than 65% of municipal waste. Food wastes in EU are estimated at about 89 million tons, or 180 kg per capita per year. EU recommends thrown food to decrease by 30% until 2025 and by 50% until 2030 in comparison to 2014. (http://ec.europa.eu/environment/basics/green-economy/managing-waste/index_bg.htm)

In 2014, Austria, Belgium, Denmark, Germany, the Netherlands and Sweden stopped the disposal of municipal garbage in landfills, while Cyprus, Croatia, Greece, Latvia and Malta still landfilled more than three quarters of its household waste. Although the waste management in the EU has improved significantly in recent decades, almost one third of municipal garbage is still landfilled, but less than half is recycled or composted, as there are huge differences between Member States. EU economy consumes 16 tons of raw materials per capita per year. Of these 6 tones become waste, half of which is landfilled.

## 2 Waste picture in Bulgaria

Bulgarian municipalities dispose 73% of garbage that they produce, but only 23% undergo treatment. It shows data of the European Statistical Office (Eurostat). The average rate in the EU of the disposed garbage is only 34%, and recycling and com-posting – 42%. It is burned 24%. Higher levels of the disposed waste in the EU than Bulgarian has in Romania, where are disposed 99% of the garbage and only 1% is processed, in Greece (82%), Croatia (85%), Cyprus (79%), Lithuania (79%), Latvia (84%), Malta (87%), Poland (75%), Slovakia (77%). (Fig. 1)

(http://ec.europa.eu/environment/basics/green-economy/managing-waste/index_bg.htm)

All waste is processed or burned in Switzerland and Germany, and in Norway, Sweden, Austria, the Netherlands, Denmark and Belgium, the percentage of waste disposed is between 1 and 3%. The average annual in EU accounts per capita is 480 kg. In Bulgaria this amount is 433 kg. Most trash per

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capita accounts of residents of countries with the highest living standards in the EU - in Switzerland (694 kg), Luxembourg (662 kg) and Denmark (668 kg).

Bulgaria is the only country in the EU, where the waste is not composted, i.e. the waste does not undergo to a natural process of controlled degradation, and entirely is disposed of in open dumpsites. These data show the European statistical office "Eurostat", distributed by the European Commission.[Fig.2].

Statistically on the amount of waste per capita Bulgaria is in the middle of the rankings along with Finland, Belgium, Sweden, Greece, Slovenia and Hungary. Cyprus is a record 700 kg per capita, followed by Luxembourg, Denmark and Ireland. Least home rubbish pile citizens of Lithuania, Romania, Slovakia, the Czech Republic, Poland, Estonia and Latvia. The largest quantities of waste treated by burning are registered in Denmark, Sweden and the Netherlands. Recycling is most widespread in Germany, Belgium and Slovenia. (http://ec.europa.eu/environment/basics/green-economy/managing-waste/index_bg.htm)

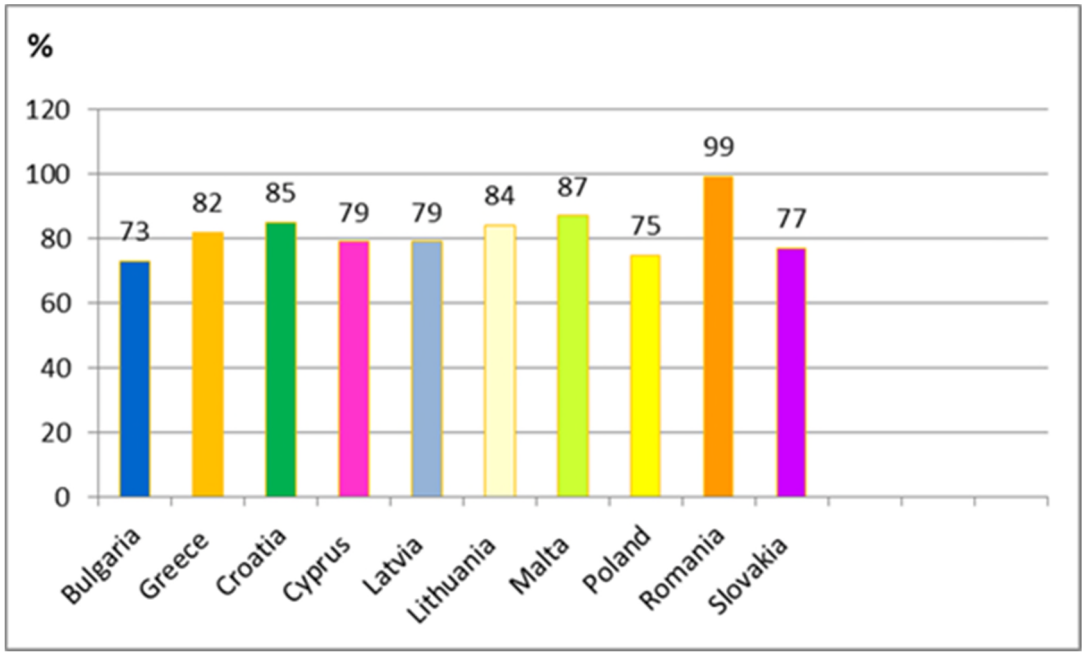


**Fig. 1.** EU Countries municipalities dispose of garbage

**Aim of the study**

To offer a solution for the processing of household waste in the municipalities in Bulgaria

**Tasks of the study**

1. To analyze the current situation in Bulgaria and to make a comparison with that in other EU countries;
2. To offer applicable into the practice solutions.

## 3 Analysis of the current situation in Bulgaria

One person in Bulgaria produces approximately 22,2 tons of garbage, while in Roma-nia this amount reaches 10 tons. In Sweden, it is 4 times higher than Bulgaria; a per-son produces almost 2 times less waste compared to Bulgarians. Per year in Bulgaria 700 thousand tons of food is wasted per year in Bulgaria, according to Bulgarian network of the UN Global Compact.

In Bulgarian waste strategy there are not specific projects for building of new regional landfills for household waste, National Center for disposal of hazardous waste and hospital waste burning. Open-

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ing of new facilities for the recycling of secondary raw materials and processing part of household waste into compost has desirable nature for the moment.

Annually in Bulgaria are discarded over 12 million tons of municipal and industrial waste. This means about 110 tons per sq. km. If we continue to bury them after a few decades there will be nowhere to do this. Furthermore, it is unclear why we should pay high cost for storage or burning if from the garbage it is possible to earn money.

Over 60% of municipal waste is biomass, which can produce compost. (http://www.nsi.bg/bg/content/2564/битови-и-строителни-отпадъци-общо-за-страната; http://www.nsi.bg/bg/content/2566/битови-и-строителни-отпадъци-по-статистически-райони-и-области)

About 20-30% of household garbage (plastic, metal, paper) can be processed and it will alleviate the problem of exhaustion of the capacity of existing landfills. Three associations in Bulgaria have undertaken to collect 150 thousand tons of packaging per year, provided that there are disposed of 325-350 thousand tones. In Bulgaria there is one company that processes plastic packages. Its processing capacity reaches 20 thousand tons per year and there is processed four times less plastic (in this half raw material comes from imports). Estimated annually 105-120 thousand tons of plastic packings only (excluding industrial waste) are disposed. Two plants for recycling plastic bottles - in Plovdiv (monthly capacity of 150 tons) and in Yambol (700 t) are planned to be built. The capacity of the eight companies that can process paper is only half loaded. Annually are treated 100-120 thousand tons. The plant for processing of tires can recycle over 4 thousand tons, which is one tenth of the waste discharges. Part of the tires is burned to obtain energy. Accumulators are processed in Montana (23 thousand tons per year) and waste oils - in Ruse (5 thousand tons per year). Processing reaches 2500-3500t per year. Metals are separate and profitable business that depends less on the centralized efforts to separate collection. Metal packages are too small - about 20 thousand tons per year. Greatest challenges are the old cars and waste from electronics and home appliances. It is known that more than a third of the cars here are more than 20 years old and practically should be used as a secondary raw material. Annually are disposed about 60 thousand cars, but a few thousand are delivered for processing and spare parts. Currently, they are mainly used for scrap and recycled small part of the tires and accumulators. [Fig.2]

From 2014 manufacturers and importers of electrical devices and electronics are facing new ecoseverity. According to a recent EU directive Bulgaria must ensure recycling of 31 thousand tons of discarded household appliances, phones and computers or 4 kg per capita. It is not clear what will be done with the collected black appliances and electronics, as far Bulgaria has no facilities for recycling.

Behind the environmental problem in Bulgaria are much money - 23 billion lv. In case it comes to dealing with another legacy - clearing rubbish and industrial pollution accumulated over decades of indifference. Most of it (almost 16 million levs) are investment costs, including only the money that the state and municipalities have to invest in the garbage are 871 million levs. Only for the building of 54 new landfills and for closing the old and clearing illegal dumpsites are provided 656 million levs

Waste incineration is negated in the world, because it is harmful. This was the first method and at first sight it seems that the only one. But in the 1980s of the last century it is shown that it causes even greater damages. Burning all kinds of waste separated the main greenhouse gas – as result are obtained carbon dioxide, and burning of biomass - as result are obtained dioxides, which are strong organic poison. Moreover, a large problem creates ash that remains. Ash from the packages is not as bad as that of the organic components. Or it should be discarded or used as filler in something, but under strict control, because it may contain heavy metals and toxic substances. And no matter how advanced the technology, there is no filter, which can stop the smell of burning biomass.

That is the reason to start looking for alternatives. In 1997 the Congress in Atlanta laid the foundation of world politics composting (processing organic waste into fertilizer). Then Jacques Cousteau said that, unless a massive production of compost does not begin, ground no longer compensates poisons. And he surprised all, predicting that till 2050 the compost will have the value of gold. (Cheremisinoff 2003).

Many authors (Jonathan W. C. Wong, Rao Y. Surampalli, Tian C. Zhang, Rajeshwar D. Tyagi, and Ammaiyappan Selvam, 2016), (Gandy M., 1994) analyze the topics like public policies focusing on reducing waste at its source, recycling, and minimizing disposal amounts; - technologies for treating and recycling solid waste; - safe, efficient treatment and disposal of hazardous and other special

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wastes; - development and maintenance of engineered landfills and landfill mining; and - legal frameworks and the use of life-cycle assessment as a tool for the waste management industry. (Jonathan W. C. Wong (Author),

The structure of waste in Bulgaria determines the processing technology - in Bulgaria biomass is 60-70% (incl. the paper). The reason for this is that we prepare our food at home and throw a lot of food waste. The main plant in Bulgaria should be a composting plant. Separately it can be recycled to 30% of waste, so as to achieve a total 90% recovery of the waste. Western countries can afford to burn their waste, because the biomass therein is 5-10% (there are restrictions on the disposal of organic waste) and are rich enough to pay for compost.

With the money down for building of the incineration plant, could be build two plants for composting and plant for production of cultivated mushrooms. Urban waste can be processed in this digest system. The milled wastes before these are purified of impurities are introduced into a chamber called digest system.

The question is what to do, if we produce so much compost. In the world there are 300 billion acres which were destroyed by erosion. Or to think how much land has been destroyed in Bulgaria. Furthermore, the compost is an alternative to chemical fertilizers. Plants that are fertilized with compost do not get sick. Interest for export is shown in the United Arab Emirates and Saudi Arabia.

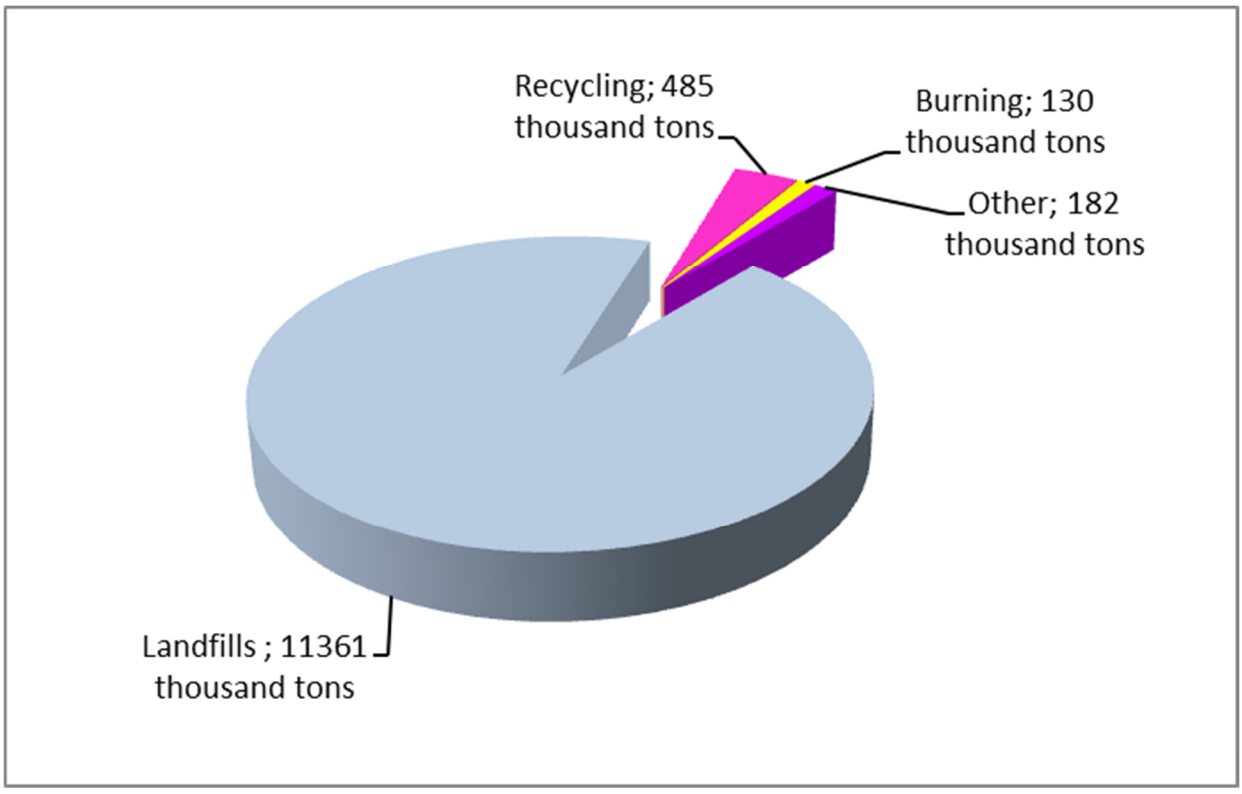


**Fig. 2.** Waste treatment in Bulgaria.

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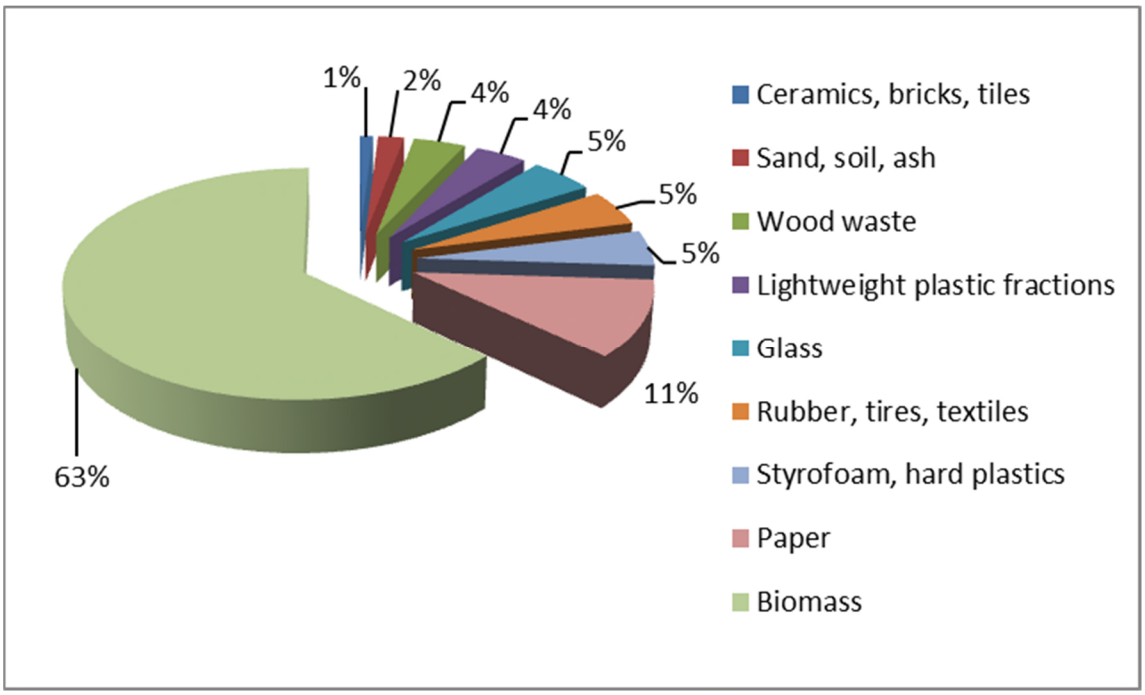


**Fig. 3.** Structure of the waste in the big Bulgarian cities

## 4 Picture of recycling in Bulgaria

In Bulgaria 2/3 from the large and 1/3 from the medium-sized municipalities are ready with their feasibility studies for the treatment of municipal solid waste. Separation plants operate in Sofia, Plovdiv, Yambol and Targovishte. Such complete installations must be established in cities with over 100 thousand tons of waste per year according to the directives in force.

For the purposes of planning, programming, management, resource provision, monitoring and evaluation of regional development are separated areas, which are divided into levels in accordance with the classification of territorial units for statistics applied in the European Union. Planning regions or so called statistical regions NUTS-2, according to the Nomenclature of Territorial Units for Statistics (NUTS) in Bulgaria are six regions, divided main objective statistical reporting of territorial units, according to Eurostat. Map of the planning regions in Bulgaria is shown in Fig. 3. [8] Based on this zoning an statistical analysis of the current situation with waste in Bulgaria was implemented (Fig. 4). (http://www.nsi.bg/bg/content/2564/битови-и-строителни-отпадъци-общо-за-страната), (http://www.nsi.bg/bg/content/2566/битови-и-строителни-отпадъци-по-статистически-райони-и-области)

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**Fig. 4.** Map of regions at NUTS 2 level in Bulgaria.(http://sust-tour.webdevc.eu/item-m936093200170.html)

### 4.1 What kind of rubbish we produce?

In the waste of a large Bulgarian city usually has 50-60% organic fraction, 30-35% high calorific fraction 7-10% material suitable for processing - paper, plastic, metal and glass. In many places in the country recyclable materials are separated, as it is economically justified to separate more than 10% of the total waste mass. Waste are composted now only in Plovdiv and Varna. To achieve in the legislative base target of 50% is mandatory effective treatment of the biological fraction. (Fig.2) (http://www.nsi.bg/bg/content/2564/битови-и-строителни-отпадъци-общо-за-страната), (http://www.nsi.bg/bg/content/2566/битови-и-строителни-отпадъци-по-статистически-райони-и-области)

### *4.2* Processing of organic waste

In the processing of organic part of the garbage (50-60% of the total) is derived me-thane - an average of 95 [m3/t]. Biogas is a material which can produce electricity. Thus processing plant can be powered independently, and the remainder of the electricity can be realized in the national electricity network. This technology is a treatment of waste anaerobically by dry fermentation, which significantly reduces costs. The processed biomass garbage has also other applications. Except for the re-cultivation of land it could be subjected to a biological drying, thus it turns into an alternative fuel source.

As a final result, the amount of disposed waste can be reduced to no more than 5-8% of the total waste, as is the case in some European countries. The vast amount of waste storage and their regular transportation are a persistent problem in all metropolises. Bins quickly overflow waste rot, emitting an unpleasant odor and destroy the aesthetic appearance of the city.

There are different solutions for waste collection. One of the innovative solutions is building a system of underground container. The first of these containers are placed in small amounts in different areas of Finnish cities. The original system of reservoirs is simple: container elongated, underground 2/3. After numerous positive reviews of citizens, it has been improved and now large-volume tanks descend into the shaft with a special elevator and the surface remains only part assuming the garbage.

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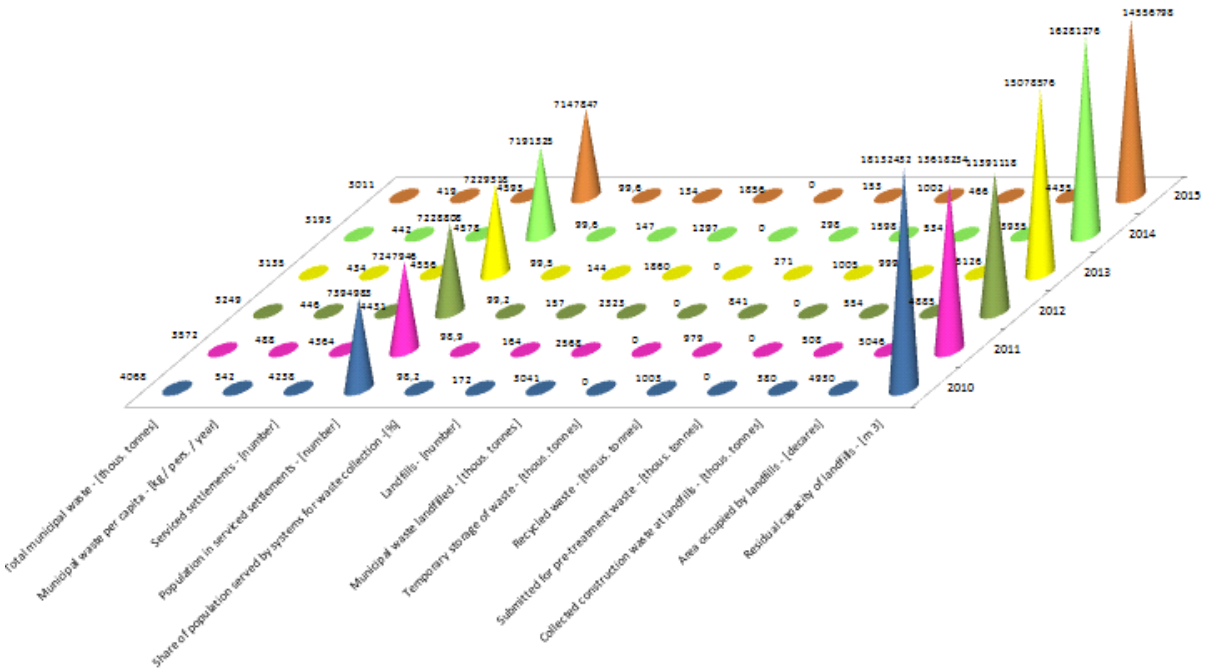
The garbage compressed under its own weight at the time of transportation occupies a smaller volume. The tightness of the container protects the environment from the pollution, unpleasant odors, and the reduced soil temperature in depth, prevents the spread of bacteria. The special cover prevents the penetration of small animals and birds, and the ability to paint in what is color - would only decorate cityscape. This system does not require frequent transportation of waste, which saves money. In some residential areas, the access to these tanks is organized by cards, to enable users to pay for the transportation of garbage. It is worth noting that in Finland the penalties for "improper waste disposal" are quite high. The creators have an idea to equip containers with scales and sensors for accurate weighing and identification of waste. These systems are very common used in the Netherlands and can be served by only one person. Truck automatically removes the container and pours its contents, which are compacted with various presses. Containers can be fitted with a system for reporting occupancy, through which, using a computer program to calculate the optimal route of the truck, so as to serve only full buckets. This may be called "technology of the 22 century", which has many advantages and facilities, but still widely used in Europe are more simplified systems whose adoption and use is more economical. They can be fully or semi-buried and are offered in different solutions to the type and size of the chamber and the shape and location of the aboveground body. There are producers of systems entirely underground containers. They consist of a concrete shaft which has a steel container and the inner protective platform that protects from falling into the pit of staff. Over the container is formed pedestrian area with various coating (rubber recycled, paving, natural stone, embossed sheet) and has above ground portions. They are characterized by excellent surface finish - stainless or galvanized steel, covered with dust or synthetic paint. The holes can be divided for disposal and mixed waste. The containers are emptied by means of using a system with two hooks, completely identical with emptying aboveground containers. The standard volume is 3 or 5 [m3] but the containers may be produced also with other volumes. The use of underground containers allows to reduce the cost of garbage disposal, presenting a more aesthetic, more practical, more hygienic and safer alternative for urban. The modern technologies for the disposal of solid waste are also directed into the use of this resource from which to obtain favorable economic results in terms of human health and the environment. (Fig. 5) On the Fig, 6 is shown a principle scheme of an modern integrated system of unsorted municipal waste treatment.




a) Municipal and construction waste

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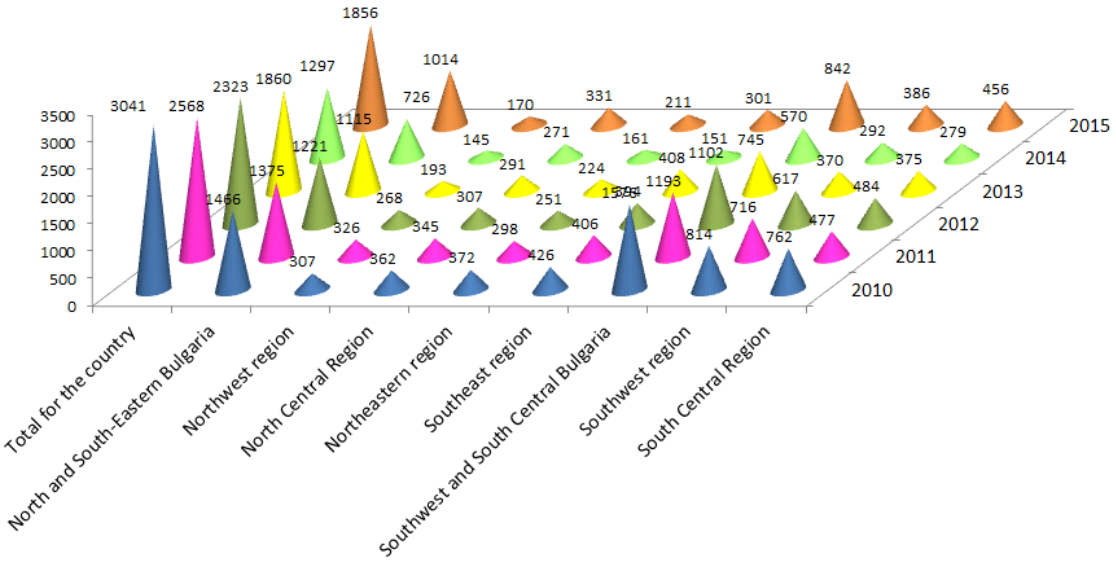
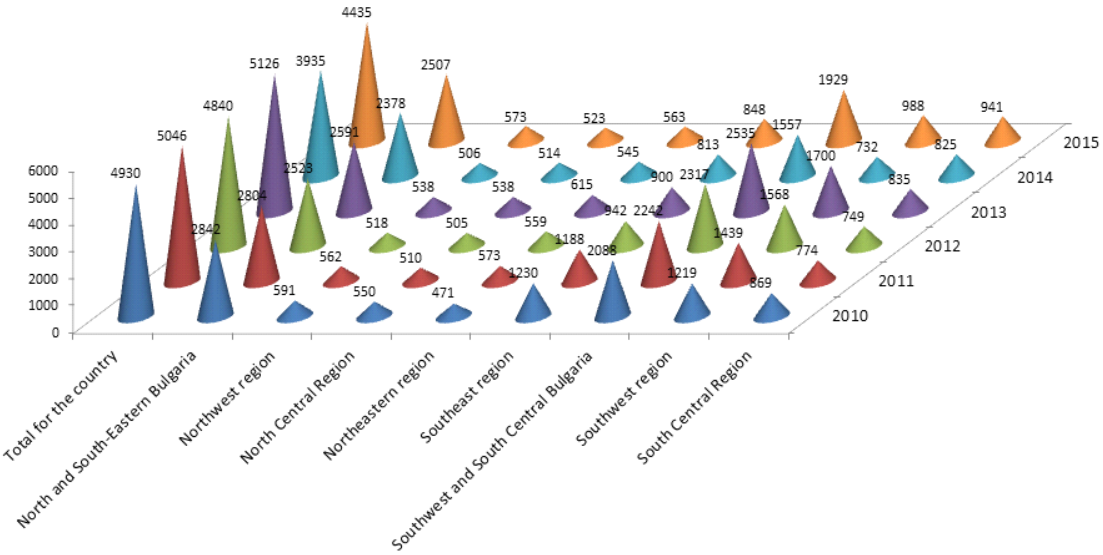



b) Municipal and construction waste landfilled by regions and areas - thous. tonnes




c) Area occupied by landfills – decares

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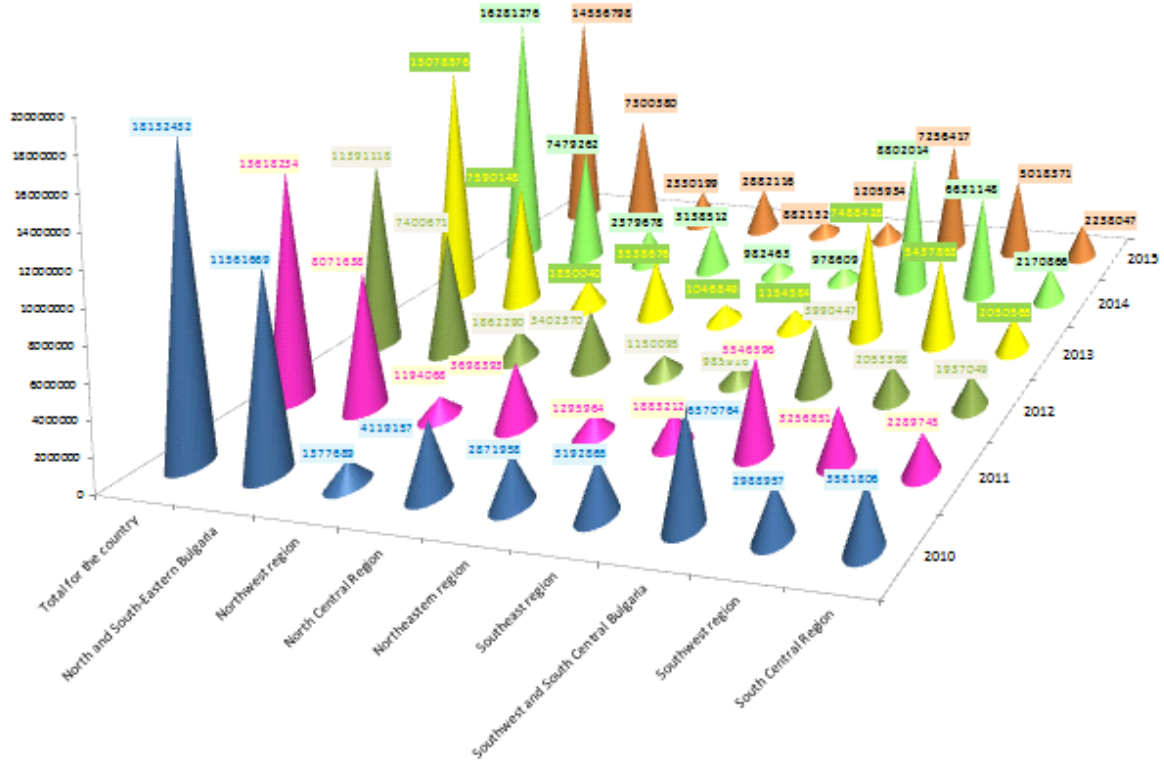


d) Residual capacity of landfills - $m^3$

**Fig. 5.** Municipal and construction waste


**Fig. 6.** The modern city: system of underground bins

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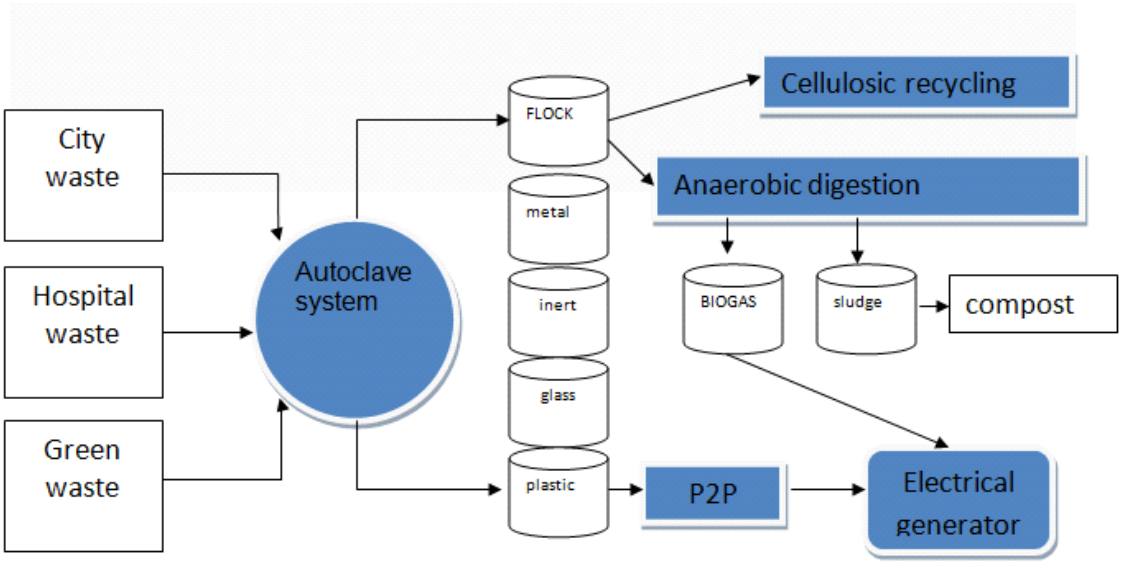


**Fig. 7.** Integrated management system of unsorted municipal waste

On the Fig. 8 is shown the complete line with two autoclave processing 50,000 tonnes of waste per year.

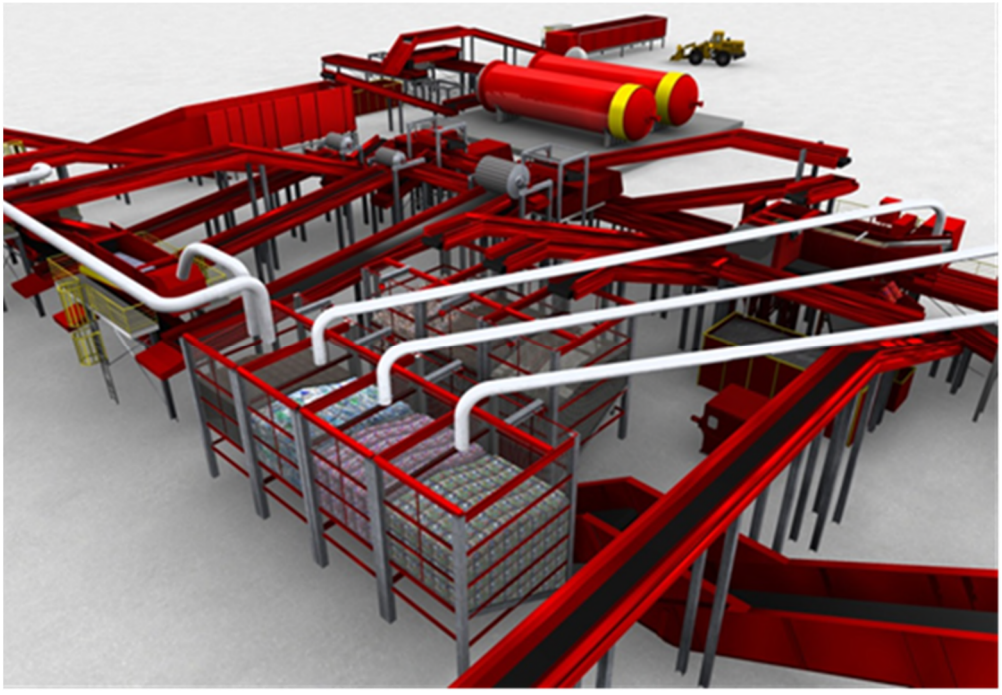

**Fig. 8.** Complete line with two autoclave processing 50,000 tonnes of waste per year.

Recovery is defined as a process in which the collected trash, without prior separation and when recycled materials in the waste are separated from nonrecyclable materials at the central facility. A typical mixed waste materials recovery facility (MRF) is shown in Fig. 9.

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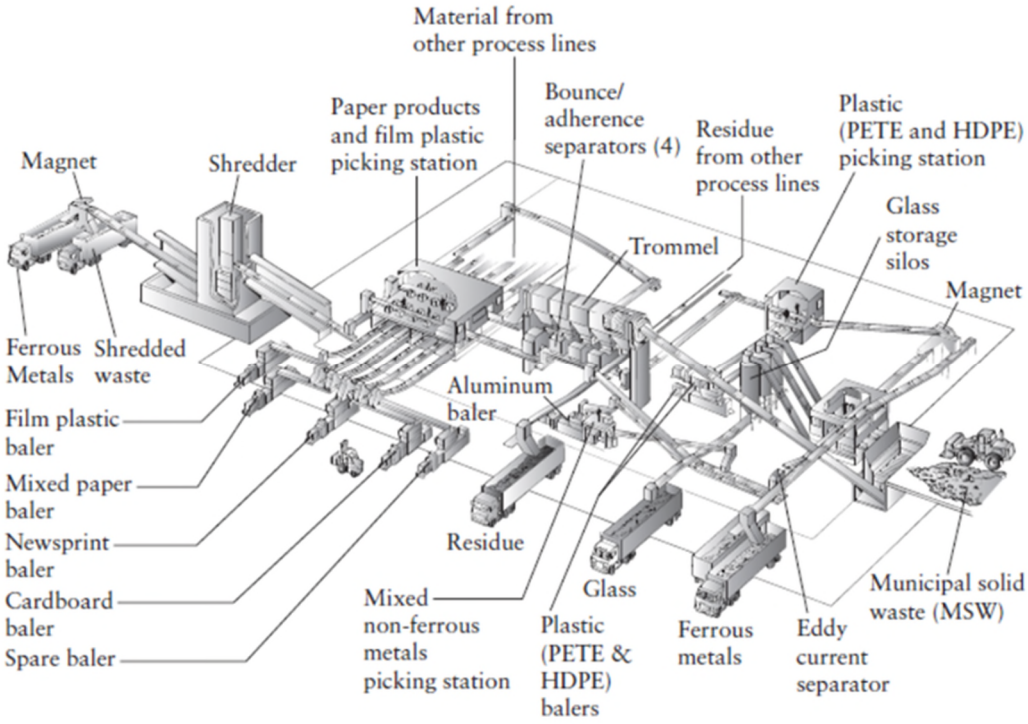


**Fig. 9.** Typical mixed-waste materials recovery facility (Worrell 2012).

## 5 Conclusion

Handling of municipal waste is defined by the Law on Waste Management. Financing of the municipal waste disposal system, including household waste within the municipal area, is arranged so that the municipality covers all expenses from its budget. It uses the following incomes for this: household payments including payments by businesses for waste collection, where municipalities as self-governing units can choose from the following options:

- A local waste fee defined as a fixed amount in the Act on Local Fees and collected from all residents in the municipality. This method is very easy for implementation and very effective. The disadvantage is that the fee cannot be collected from individuals without permanent residence although they live in the municipality and produce waste there.
- A municipal waste fee is calculated by the municipality according the real costs of the system and paid by building owners for all persons living in them. The ad-vantage is the ability for adjusting the fee on the base of the real costs and levying it from everyone who lives in the place and produces waste. The disadvantage is that it is difficult to check whether everyone really pays.
- A new effective approach may be the payment for mixed waste collection on the base of the price determined by the collecting company directly from citizens when they hand over their waste for collection to a landfill or incinerator. This system maximizes the stimulus to separate waste and reduce its quantity, as the payment is not an annual lump sum but for the actual amount only. The disadvantage is that it may motivate irresponsible citizens to dispose of their waste illegally in the wild nature, incinerate at home, etc.
- Another source of municipal income is payments from companies operating the collective systems, which leave part of the recycling fees collected to the municipalities in exchange for providing the collection points for them; incomes from the sale of secondary raw materials that the municipality has collected from the citizens; since these incomes are sometimes insufficient to cover the whole system, municipalities will add other municipal incomes.
- Municipal self-governments have broad opportunities for the financing method thanks to the system. They also have an option to increase their incomes by cooperating more efficiently with the collective systems or selling secondary raw materials in more profitable ways or higher quantities.

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At the same time, citizens have the option, if they do not hand over their sorted secondary raw materials to the municipality free of charge, to sell them to companies that do commercial collection and repurchase of waste (primarily metals, papers, plastics etc.).

Composting is receiving increased attention as a means of solid waste (municipal solid waste, bio solids, yard trimmings, food industry wastes etc.) disposal. It is a cost-effective and environmentally friendly component of organic solid waste management. Increased solid waste production and a decrease in available space for landfills have resulted in an increased demand for composting technology. Composting is a form of recycling and is the only technique discussed that may be viewed as approaching P2P (peer to peer). Composting can be linked to sustainable agriculture, anaerobic digestion can be linked to sustainable energy, deconstruction can be linked to green architecture, the residual screening and zero waste research facilities are clearly linked to sustainable economic development and job creation. (Connett P., 2013) – Fig. 10.


**Fig. 10.** Zero waste as a tool to advance toward sustainability (Connett P., 2013)

The benefits of using compost include:

**Soil enrichment**

- Adds organic bulk and humus to regenerate poor soils
- Helps suppress plant diseases and pests
- Increases soil nutrient content and water retention in both clay and sandy soils
- Restores soil structure after reduction of natural soil microbes by chemical fertilizer
- Reduces or eliminates the need for fertilizer
- Combats specific soil, water, and air problems

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### Pollution remediation

- Absorbs odors and degrades volatile organic compounds
- Binds heavy metals and prevents them from migrating to water resources or being absorbed by plants
- Degrades, and in some cases, completely eliminates wood preservatives, petroleum products, pesticides, and both chlorinated and nonchlorinated hydrocarbons in contaminated soils

### Pollution prevention

- Avoids methane production and leachate formation in landfills by diverting organics for composting
- Prevents pollutants in stormwater runoff from reaching water resources
- Prevents erosion and silting on embankments parallel to creeks, lakes, and rivers
- o Prevents erosion and turf loss on roadsides, hillsides, playing fields, and golf courses

### Economic benefits

- Results in significant cost savings by reducing the need for water, fertilizers, and pesticides
- Produces a marketable commodity and a low-cost alternative to standard landfill cover and artificial soil amendments
- Extends municipal landfill life by diverting organic materials from the waste stream
- Provides a less costly alternative to conventional bioremediation techniques

The greatest recycling challenge facing solid waste infrastructure is not in the process of collecting, separating, and supplying resources recovered from the waste stream, but in doing so at a competitive cost, and in marketing the materials at a price, quality, and quantity competitive with virgin materials.

Simply collecting obvious materials and hoping someone will pay enough to produce a profit is not recycling. Like any other business venture, it must be carefully planned with the application of life-cycle costing tools.

This publication outlines the research scope of a future joint work of a team of Industrial Management Department of Technical University of Varna with Varna Municipality. The beginning is with the research project "Opportunities for Development of Innovative Strategy for Intelligent Specialization of Varna Municipality". Eco-innovation is not limited to new technologies or products. It can also lead to changes in patterns of consumption and production and have a wider transformative effect. Systemic eco-innovation connects many interconnected innovations that improve or create new functional systems. Such innovations should involve many players, including government, businesses and citizens, in the regional system and in the value chain.

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