# BIOELEKTRA

## A Circular Economy Business Model Case

Boleslaw Rok, Institute of Innovative Economy

Dominik Stanny, Institute of Innovative Economy


*Source: Bioelektra*



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Table of Figures





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# Table of Contents





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# Executive Summary

This report presents the results of the Bioelektra case study, selected in the framework of the R2PI project, among 17 other cases. The mission of this company is to change the way people think of waste management, by using advanced technology. The information contained in the report is based on the methodology designed within the framework of the R2PI project to understand the characteristics of the business model, evaluate its outcomes and identify the main barriers and enablers.

Bioelektra has developed and utilized the innovative technology for municipal solid waste as a complementary solution to waste management. The activity of the company is based on a mechanical-heat waste treatment (MHT) called RotoSteril, different from traditional technology of municipal waste treatment. Waste is sterilized at high temperature and pressure, which kills all microorganisms in waste and makes it odourless. Subsequently sterilized waste is sorted into usable fractions of different secondary raw materials, organic fraction and RDF. These fractions can be further used to other processes and products. Usually these fractions are sold to recyclers.

The identified business model of Bioelektra is resource recovery. The contribution of Bioelektra to the closed loop is primarily based on a very high recycling rate - up to 96% of municipal solid waste stream with no need of separate collection. At the municipal level in different countries one can still find a significant amount of waste without separate collection. This innovative technology enables lower “gate fee” for municipalities (and finally for residents) and high revenue from fractions.

The report also presents an assessment of the circularity of the business model. Traditionally, the waste management sector in the EU was described as a “collect and dispose” operation: collecting mixed waste streams from municipal and commercial sources and disposing of the waste to landfill or through incineration. The waste management system in the circular economy will have to go beyond such an end-of-pipe approach to become an integral part of an economy, closely linked to patterns of production and consumption. Circular product design should be based on the feedback from the waste management sector concerning the ways to remanufacture, dismantle and recycle. At the same time the waste management sector should become a partner in developing circular business models focused on waste prevention and turning waste into resources.

Activity of Bioelektra Group is based on the improving circular economy model since the very beginning. The aim of establishing the company was to implement and deliver the technology of waste treatment allowing recovery every material from waste. Bioelektra was focused on reducing the negative impact on the environment in waste management. The company was involved in the process that allow to obtain clean secondary raw materials and organic fraction, ideal for recycling purposes.

It has now the full control concerning the composition of final products – recyclates - that they obtain. Those products can circulate in the economy for longer. But Bioelektra is not a manufacturer, so real circularity is out of their business model. Bioelektra fulfils its own function towards the circularity of the economy by addressing some of the challenges, but they don’t have complete control over their remanufactured products.

As shown in the report, Bioelektra has created a waste treatment technology that can unveil resource potential in waste. It allows for simple methods of waste management in the cases where there is no segregation-at-source. The technology respects local community by making waste odourless. It is also the most financially viable waste treatment technology – according to managers from the company, as municipal solid waste is sterilised and turned into resources. It creates new opportunities for local economies in different parts of the world by delivering streams of recycled resources as secondary raw materials to the market by achieving a diversion rate of over 96% from landfill.

Crucial for the business success of Bioelektra is the legal framework. Some provisions of EU law, especially in Directive on Waste, creates many opportunities for Bioelektra to expand. The constant increase of recycling level, which is declared by EU can create much bigger market for Bioelektra



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 730378

services. Limiting the biodegradable municipal waste going to landfills can create another possible opportunity, as well as a radical decrease in the amount of waste disposed in landfills, while increase of recycling and the recovery of waste.

Based on the analysis, it is concluded that the resource recovery CEBM is replicable and transferable, especially that Bioelektra's technology is fully scalable to the size of the waste stream and can be adjusted up and down in scale during its operations by adding or taking out autoclaves. Autoclaves are easy to transport, and installation is rather fast. Most of the investment cost is machinery and equipment which makes it ideal for external financing (bank or leasing). The construction costs are usually 10-20% of the total CAPEX. Technology is 100% environmentally friendly – it is odourless, there is no leakage, fumes and sewage system needed thus public acceptance and support can be expected.

All these requirements are easy to meet thanks to Bioelektra technology – which creates many possibilities for strategic development of the company. However, the regulatory framework on the national level is now the biggest threat for Bioelektra, especially different interpretation of the EU legal requirement in different countries.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# 1 Introduction

## 1.1 Background and context

R2π – Transition from Linear to Circular is a European Union Horizon 2020 project focused on enabling organisations and their value chains to transition towards a more viable, sustainable and competitive economic model to support the European Union's strategy on sustainability and competitiveness.

R2π examines the shift from the broad concept of a Circular Economy (CE) to one of Circular Economy Business Models (CEBM) by tackling market opportunities and failures (businesses, consumers) as well as policy opportunities and failures (assumptions, unintended consequences). Its innovation lies in having a strong business-model focus (including designing transition guidelines) as well as in the role of policy development (including designing policy packages).

The ultimate objective of the R2π project is to accelerate widespread implementation of a circular economy based on successful business models and effective policies:

- to ensure sustained economic development,
- to minimize environmental impact and
- to maximize social welfare.

The mission of the project is therefore to identify and develop sustainable business models and guidelines that will facilitate the circular economy, and to propose policy packages that will support the implementation of these sustainable models. A core part of this project is to work with organisations who are on the journey towards developing circular economy business models, as well as those who have the ambition to do so but haven't yet begun.

The 18 chosen cases covered all five priority areas highlighted in the EU Action Plan on the Circular Economy: plastics, food waste, biomass/bio-based, important raw materials, and construction & demolition. Additionally, the cases were selected to ensure learning in each of the seven business model patterns defined by the R2Pi project: re-make, re-condition, circular sourcing, co-product recovery, access, performance and resource recovery, and these will be discussed in more detail in this report. To gather wide-ranging lessons from differing company sizes and maturities, the following were selected: 7 large corporations, 8 small and medium enterprises, 1 public entity, 1 entire value chain with both public and private organisations and 1 ongoing social project.

This report presents the case study of Bioelektra. It was chosen due to the innovative technology used for a municipal solid waste treatment, based on a very high recycling rate - up to 96% of the stream. The next section provides a more detailed overview of the case organisation's business.

## 1.2 Business overview

Bioelektra Group SA (limited liability company) was founded in 2013, in Warsaw, Poland. Bioelektra has designed and implemented a highly innovative technology of mechanical-heat waste treatment (MHT) called RotoSteril. Bioelektra's technology is more effective and less expensive than mechanical biological treatment (MBT) technology widely used in the waste management, considering both capital expenditures and operating costs. MHT technology is scientifically verified, patented and tested in practice. It is the first Polish technology notified to BAT conclusions in the field of waste management. It aims to recycle and recover up to 96% of municipal solid waste stream. One of advantages of MHT technology is its ability to process both unsegregated solid waste (with no need of separate collection) as well as waste collected selectively.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Bioelektra's technology has been implemented in the first MHT facility in 2014 in Rozanki (northern Poland). Nowadays the company is in the intensive growth stage and is seeking new markets. The number of employees in 2018 is 34 – in Rozanki facility and office. The company is discussing initial conditions with local partners in different countries for implementing their technology, analysing legal environment and finding the best solutions to start operations, both in the European Union, as well as outside EU. Countries where Bioelektra runs projects in the initial phase are: Slovakia, Czech Republic, Germany, Netherlands, France, Spain, Italy, Greece, UK, Croatia, Russia, Belarus, Ukraine, Kazakhstan, Azerbaijan, USA, Australia, Israel, Argentina, Chile.

Bioelektra Group cooperates with local authorities, enterprises and organizations engaged in waste management and seeking more effective solutions, as well as institutes and research bodies, interested in further waste management technology development. Their mission is to change the way people think of waste management. Thanks to their approach, municipal waste can be a source of useful materials, fertilizer and energy, with no harm to environment and with full support of local societies.

In 2017 Bioelektra Group became the winner in "The Dell Circular Economy People's Choice Award" in category most inspiring, innovative solution, stimulating circular economy development "The Circulars 2017". The company received this award during the World Economic Forum in Davos. The company is also the winner of "Energy Globe National Award 2017" as the best Polish project for environmental protection and sustainable energy usage. For RotoSteril as the technology with significant potential for development it received honourable award "GreenEvo – Green Technology Accelerator".


*Source: Bioelektra*

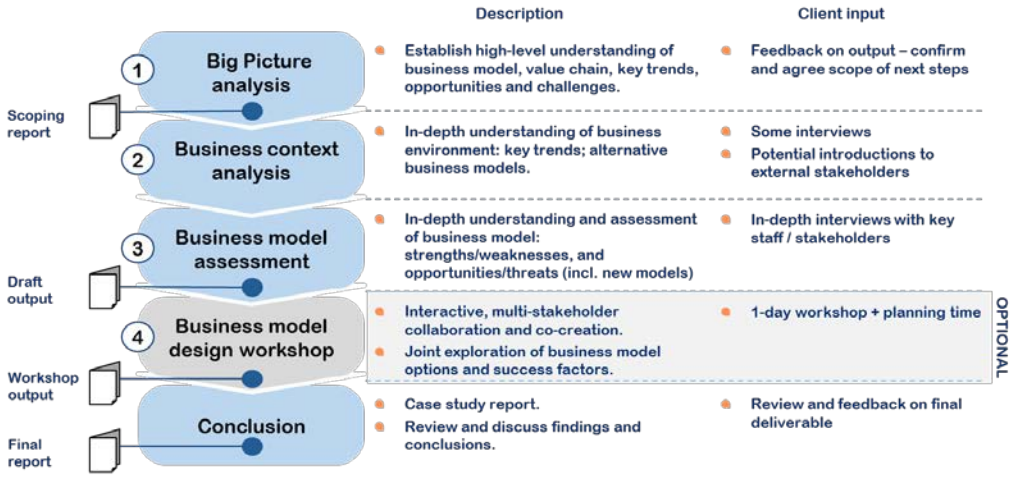
## 1.3 The case study analysis process

The case study process was structured in three main steps and concludes with this document as the final report (see diagram below).



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

**FIGURE 1: OVERALL STRUCTURE OF THE CASE STUDY**




*Source: R2Pi*

The different steps taken along the case study research were addressed. The kick-off meeting took place on the 2.11.2017 in the company headquarter, with the participation of CEO and researchers from the Institute of Innovative Economy. The first, initial interview was conducted on 11.12.2017 with CEO. The next meeting was on 15.01.2018 with the management team, based on the developed methodological tools for business context analysis and business model assessment. Some additional internal documents were presented and discussed by company managers.

The main in-depth interview with CEO took place on 2.02.2018. The meeting with the management team was conducted on the 16.02.2018 and focused on analysing and discussing the business model circularity. Desktop research was conducted, including email exchange with the company representatives to clarify information and get additional data. The final step was the site visit in Rozanki on 13.04.2018. The case report was presented to the company owners during a meeting on 9.10.2018.


*Source: R2Pi*

## 1.4 Report outline

The first chapter is providing an overview of the case and case study process. Chapter 2 presents the big picture of the business environment, reporting on the context in which Bioelektra operates and the key external factors. Chapter 3 is an analysis of the business at the building block level of the business model, including the circularity of the business, the financials and the strengths and weaknesses. Chapter 4 draws conclusions about the current state of the business and its future potential.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# 2 Bioelektra's business context analysis

## 2.1 Scope of the business context analysis

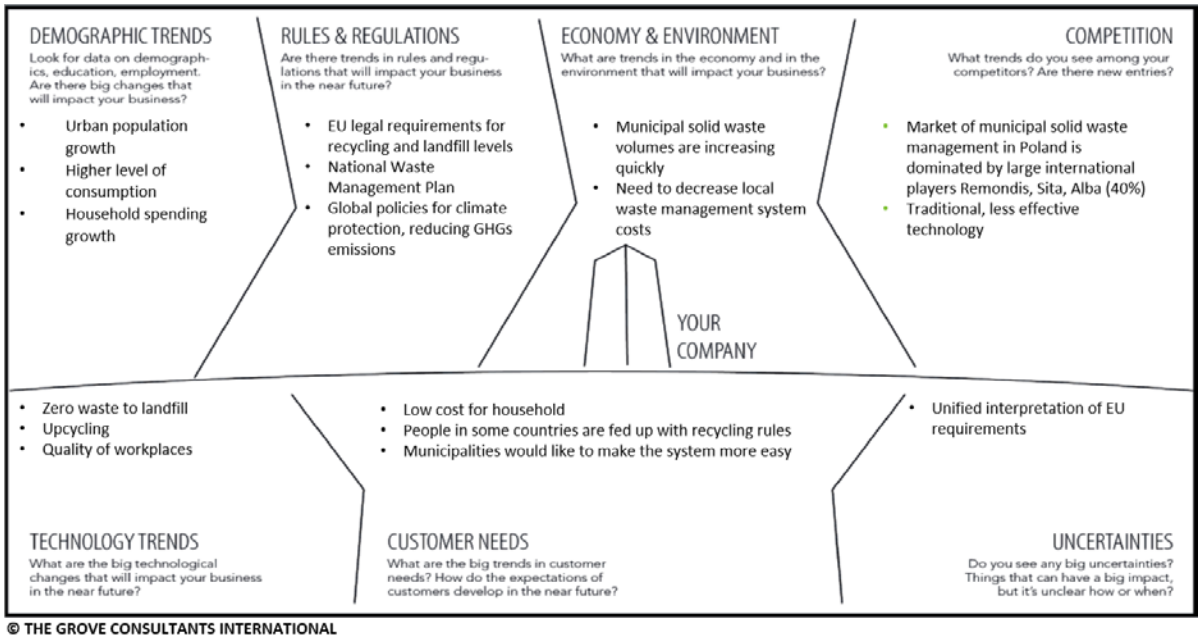
The objective of the context analysis is to identify the main external factors that are to be considered to explain the success or failure of Circular Economy Business Model (CEBM), as well as its potential role in accelerating the transition towards a Circular Economy.

The business context research was carried out in two stages. In the first stage, the case study team conducted desk research to identify the EU policy, the country and sector-specific factors that may potentially affect the business model from an industry perspective. In the second stage, the team conducted interviews with relevant key stakeholders.

## 2.2 Contextual factor analysis

This section presents the different factors that affect the context of the waste management industry, from a Circular Economy perspective. Information presented is based on desktop research and – partly - on internal documents from the legal department of Bioelektra.

*FIGURE 2. CONTEXT MAP CANVAS*






*SOURCE: OWN ELABORATION*

The different factors that appear in the context map (Figure 1) will be described below, according to different categories, namely: demographic factors, rules & regulations, economy & environment, competition, technology trends, customer needs and uncertainties.

### 2.2.1 Demographic trends

The growth of population and rising standards of living means that the consumption of goods and energy is increasing. One can observe especially the dominant trend of increase of the urban



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

population and as a result increase of municipal solid waste (MSW). In 2012, the worlds' cities generated 1.3 billion tonnes of solid waste per year, amounting to a footprint of 1.2 kilograms per person per day. With rapid population growth and urbanization, municipal solid waste generation is expected to rise to 2.2 billion tonnes by 2025.

Advances in technology mean that consumers own and use many more personal devices and update them more often. Consumption has changed dramatically, as consumers have much more choice and products are designed to have shorter lifespans (obsolescence) with many single-use and disposable products. Moreover, unhealthy lifestyle as well as industrialization leads to the development of chemical, oil & gas, automobile and medical industries, which further increases waste generation.

Waste generation rates are rising around the world. The average amount of MSW generated by each of about 512 million inhabitants of the European Union was accounted as 477 kg per year in 2015. Globally, municipal solid waste volumes are increasing quickly – even faster than the rate of urbanization. By 2025, global waste production is set to double and over 70% of global waste will be generated by emerging economies. The increase of streams of MSW is fastest in China, parts of Eastern Europe and the Middle East. There are different efforts to reduce or even stabilize the MSW stream all over the world through citizen education, governmental or local legislation or advancement of the new patterns of production, especially in the packaging industry. In short term the proper waste management is crucial for the circular economy development.

For the most part the waste management system provides the end of pipe solutions whereby increasing amounts of discarded materials are buried, dumped out at sea or turned into ash, creating the need for the extraction of further raw materials. Improper waste management can bring serious health and environmental risks and adds to the uncontrolled rise in carbon emissions. Waste disposal in landfill sites causes a potential hazard for the human health as they release substantial amounts of gas, odours and pollutants to the environment. The best solutions of MSW management should not only be environmentally sustainable but also cost-efficient and socially acceptable. We are losing significant opportunities to reclaim as many resources as possible and to improve resource efficiency and to enhance the transition towards a circular economy.

Managing waste properly is essential for building sustainable and livable cities for a growing population, but it remains a challenge for many countries and cities ("Circular City", ZeroWaste). Cities present an opportunity because the human population is rapidly urbanizing. In 2014, 54% of the world's population were residing in cities and by 2050 this figure is expected to be close to 70%. Harnessing this wave of urbanization as a means for delivering sustainable human settlements could represent a major opportunity for reducing ecological footprint. Modern cities have been generally designed as extractive engines drawing resources from natural systems, processing these resources to generate value, and producing wastes whose impacts are externalized, but the changes are implemented. It will require improvement of urban performance through ongoing urban metabolism assessment to ensure urban sustainability performance targets are met or even exceeded so that cities can be a major force in reversing planetary boundary challenges.

### 2.2.2 Rules and regulations

Waste management is a complex field which goes beyond prevention, collection, treatment, and disposal of waste, embracing a larger scope of socioeconomic issues, governmental regulations, policy choices, and local requirements. It is about protecting, preserving, and improving the quality of the environment, human health, ensuring rational utilisation of natural resources. EU's economy currently loses a significant amount of potential secondary raw materials which are found in waste streams. Only 43% of the municipal waste generated is being recycled, with 31% being landfilled or incinerated - 26%.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

There are several factors that influence the legislation, which are largely intertwined. There is a need for political will, a willingness to pursue changes but also a strong support on the local level. While the EU sets a direction, underlying the necessary shift towards the circular economy, waste management is delivered and implemented mostly at the national level. Waste management contains a multi-level governance system, embracing central governments for setting strategies, creating national plans, then regional and in most cases local authorities for designing and implementing policies and organising tools for waste collection, treatment, and disposal. Government regulations, taxes and support schemes play an important part in the development of this sector and can encourage the new technologies development and innovative solutions.

In March 2017, the European Parliament adopted its position on the review of the four key waste directives with more ambitious targets and provisions compared to the Commission's proposals issued in 2016. For example, in some of its 234 proposed amendments to the Waste Framework Directive (WFD) and to accelerate the switch to a circular economy, the Parliament tightened the Commission's proposed targets for the preparation for reuse and recycling of municipal solid waste and called on the Commission to examine the opportunity to set EU waste prevention targets.

The revised legislative proposals on waste, as a part of EU Action Plan for the Circular Economy set clear targets for reduction of waste and establish an ambitious and credible long-term path for waste management and recycling. Key elements of the revised waste proposal include:

- A common EU target for recycling 65% of municipal waste by 2030;
- A common EU target for recycling 75% of packaging waste by 2030;
- A binding landfill target to reduce landfill to maximum of 10% of municipal waste by 2030;
- A ban on landfilling of separately collected waste;
- Promotion of economic instruments to discourage landfilling;
- Simplified and improved definitions and harmonised calculation methods for recycling rates throughout the EU;
- Concrete measures to promote re-use and stimulate industrial symbiosis - turning one industry's by-product into another industry's raw material;
- Economic incentives for producers to put greener products on the market and support recovery and recycling schemes (e.g. for packaging, batteries, electric and electronic equipment, vehicles).

The Parliament's amendments to the Landfill directive also call for a maximum of 5% of total MSW to be sent to landfills in 2030, compared to 10% in the Commission's proposal. The Member States are free to set even tighter targets and some of them are prepared for it already. Waste management planning is one of the key tools for authorities to convert the principles of EU waste legislation at national, regional, and local level within their Member State. The Member States' authorities are obliged to establish one or more waste management plans (WMP) pursuant to Articles 1, 4, 13 and 16 of the WFD.

Waste legislation in Poland was introduced before entering the EU in 2004. Currently, municipal waste management is regulated by the following Acts: Act on Keeping Cleanliness and Order in Municipalities, Environmental Protection Law; Act on Obligations of Businesses in Management of Certain Wastes and on Product Fees; Act on Waste; Act on Packaging and Packaging Waste Management. The definition of municipal waste provided in the legislation includes household waste, as well as non-hazardous wastes produced in other places, which by their nature or composition, are like household waste. Waste management in Polish law means waste generation, collection, transport, and treatment of waste including the supervision of such activities. The Act on Keeping Cleanliness and Order in Municipalities obliges the municipalities to organise an efficient system of collection, transportation and treatment of municipal waste.

The governmental activity concerning waste management in Poland is directed to hierarchy of waste strategy, pointed out by EU and implements it in every administrative level. Different procedures are



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

included in National Waste Management Plan (NWMP) as an effect of Polish obligations, resulting from EU membership and defined in Polish National Environmental Policy. The most desirable activities are as follows: first – waste avoidance, next – waste processing for re-use and recycling, but also procedures of waste treatment by incineration and ultimately waste disposal in a landfill. All these actions are undertaken to minimize possible negative effects of waste on natural environment.

### 2.2.3 Economy

Closing the loop is viewed as a driver to transform economy and impact labour market. According to Global Waste Management Outlook (ISWA, 2013) it offers a systematic approach to management of 2 billion tonnes of municipal solid waste and 7-10 billion tonnes of urban solid waste from households, commerce, industry and construction generated per year. There is a potential impact of improved waste management on reducing GHG emissions across the economy at the level 15-20%. It can also contribute to the reduction of emissions of methane, a powerful greenhouse gas (GHG) and prevent 1.3 billion tonnes of food waste generated every year.

In the years 2000-2010 in Europe employment in waste and resource management doubled to reach 2 million people, while approximately 15-20 million people work in the small-scale entrepreneurial informal waste sector worldwide.

The global waste management market was valued at USD285 billion in 2016, and is expected to reach USD435 billion by 2023, registering an annual growth rate (CAGR) of 6.2% from 2017 to 2023. Waste management is collection, transportation, and disposable of garbage, sewage, and other waste products. It involves treatment of solid waste and disposal of the products and substances in a safe and efficient manner.

The waste management market is segmented based on waste type, service, and region. Based on waste type, it is bifurcated into municipal waste and industrial waste. Based on service, it is classified into collection services and disposable services. Collection services is further classified into collection & transportation, storage & handling and sorting. Disposable service is segregated into landfills, recycling, compositing & anaerobic digestion, and others. Based on region, it is analysed across North America, Europe, Asia-Pacific, and LAMEA.

### 2.2.4 Environment

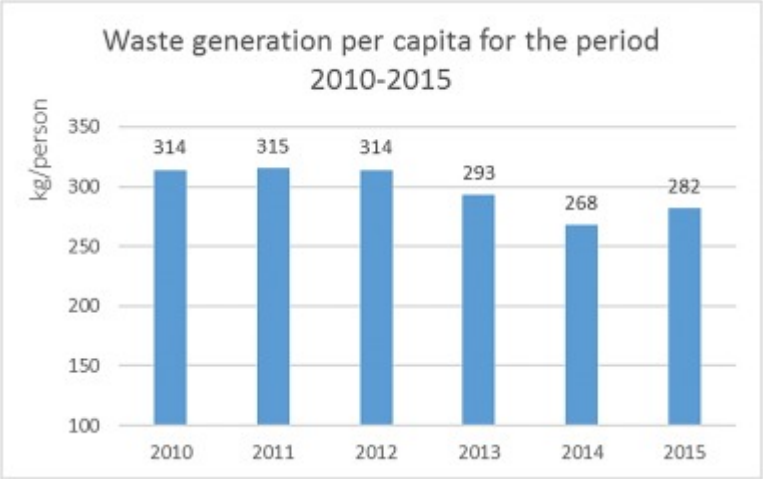
Despite great potential of the renewable raw material, it seems not to be sufficiently made use of, not only in Poland, but also in majority of countries. In 2015, 10.9 million tonnes of municipal waste were generated (282 kg per capita) in Poland, which was about 8% of all waste produced in the country. The amount of municipal waste production is related to individual consumption, but also is influenced by the discarding of waste on illegal dumps or disposing in inappropriate household conditions, insufficient control by the municipalities.

In Poland, solid fuel boilers are very popular. Unfortunately, many citizens are burning garbage in them, having “free” heat and a solution of the rubbish problem without taking into consideration any effect on the environment and human health. Since the Act on Keeping Cleanliness and Order in Municipalities significantly changed in 2012, the amount of waste generated and collected is the same, because all inhabited real estates were covered by a waste collection system.



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 730378

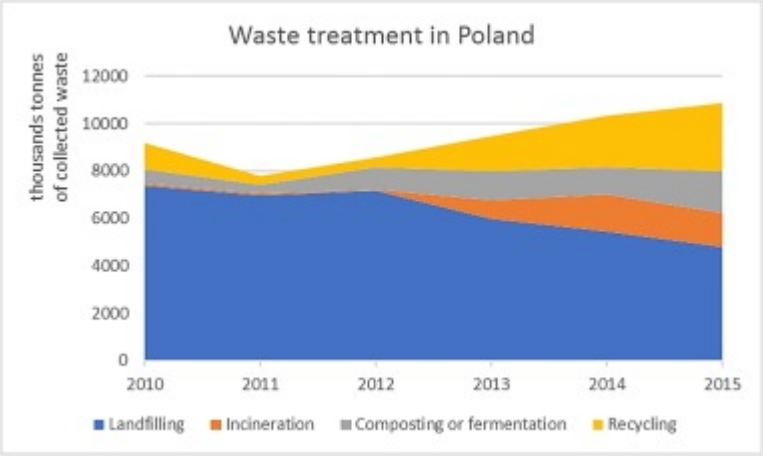
*Figure 3. Waste generation per capita in Poland*




*Source: Central Statistical Office, Warsaw, 2016*

Next Figure shows the changes in waste management in recent years. There is a gradual decrease in the amount of waste disposed in landfills, while recycling and the recovery of waste is increasing. This trend is important, because Poland should achieve the required recovery and recycling rates by 2020.

*Fig. 4. Waste treatment methods in Poland for the period 2010–2015*




*Source: Central Statistical Office, Warsaw, 2016*

Poland, having joined the EU, committed itself to implementing many changes related to waste management. The aim of the policy of local governments is to prevent the generation of municipal solid waste as much as possible but also to increase the emphasis on segregating the waste at the place it was produced. The implementation of EU directives and the development of strategic documents such as the National Waste Management Plan (NWMP) have made a change in the waste management approach. One of the changes was the establishment of selective collection of MSW, with the issue of collecting the waste by the residents being a priority.

The primary focus is the reduction of virgin resource consumption, pollution and waste in each step of the life cycle of products. Optimising the entire system requires improved manufacturing processes through closed loop material flows that internalize environmental externalities linked to virgin



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

resource extraction and the generation of waste. Negative impact on the natural environmental is connected to ecological footprint, $CO_2$ and other greenhouse gases emission, excessive water consumption, natural resources depletion (air pollution, land degradation, mineral resources, deforestation, biodiversity under threat, animal exploitation production) and climate change. Inefficient waste management becomes a burden for the society and environment as well as increases production costs.

### 2.2.5 Competition

Europe accounted for the highest market share of municipal solid waste management services in 2016 and is expected to maintain its dominance throughout the forecast period. This is attributed to rapid industrialization in the region and growth in measures toward adoption of recycling technologies. Moreover, legal regulations to reduce air pollution and encourage proper handling and disposal of waste stimulate the market growth in the region.

The market of municipal solid waste management in Poland is dominated by several large international players operating throughout the country (approximately 40%, including Remondis, Sita, and Alba). Apart from these, at the regional level there are municipal enterprises or companies belonging to inter-municipal associations that bring together the authorities of neighbouring local self-governments. The significant surplus of processing capacity of existing installations is one of the entry barriers and a deterrent for new players.

The demand for waste management services depends mostly on two factors: the indicator of municipal waste production per person (303 kg per capita in 2016 in Poland) and the population of the country. The prognosis for Poland is optimistic from the business perspective, e.g. the stream of municipal waste is supposed to increase in the next few years even though at the same time the population forecast is rather pessimistic.

According to National Waste Management Plan 127 installations using mechanical-biological technology were operating in Poland in 2015. Their mechanical processing capacity is estimated at about 9.4 million tonnes and biological processing capacity at about 4.1 million tonnes. The mass of municipal solid waste collected in 2016 is estimated at about 11,6 million tonnes. The majority (81%) of municipal waste in 2016 was collected from households. The total mass of municipal solid waste collected selectively is slowly but steadily increasing (from 23,4% in 2015 to 25,2% in 2016).

Additionally, recyclate markets in Poland are deregulated and unstable. There are over 4,000 registered companies, but only a small part of them operates. The closure of China for the export of recyclates caused a drop in the prices on the Polish markets. Thus, the revenues from secondary raw materials (especially plastics) sale are at risk and could not be treated as main source of income.

### 2.2.6 Technology trends

The selection of technology for treatment and disposal of solid waste vary from one country to another and depends on the types of waste, composition, infrastructure, land availability, economic aspects, recycling strategy, public awareness, value of waste, energy availability and demand, environmental impact and legal requirements. There is no universal best system for waste treatment and disposal, but available technologies can only be determined locally, depending on both the composition and the quantities of waste generated, the access to the disposal technologies and the market demand for the product derived from waste treatment such as reclaimed materials, compost and energy.

UE legal requirements for recycling and landfill levels will cause the market to increase and more efficient technologies will be needed soon. A lot of efforts was put already to compare the overall



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

environmental performance and energy efficiency of waste treatment technologies but, in general, no consensus has been reached, as different alternative treatment strategies are found to be preferable in different conditions and regional settings. In EU countries, the processing of mixed municipal waste is based on waste treatment in mechanical and biological (MBT) installations and thermal processing plants. The experience gained from the operation of these installations, particularly in the aspect of material recycling is not fully satisfactory. To achieve a higher level of reuse and recycling of municipal waste, which is expected to be at least 65% by 2030, efforts to improve waste quality needs to be made.

Innovative solutions are visible at the mechanical sorting stage of the waste. Modern optical separators are used for such operations. These devices select glass, plastic and other materials with a distinction of their individual colours of waste mass. This material is ready for recycling. Important in new system of waste management are waste-to energy installations. One of the opportunities of reuse of waste is the acquisition of alternative fuels – Refuse Derived Fuel (RDF). Alternative fuels are substitutes for conventional fossil fuels. The alternative fuels are produced from high calorific waste, generated by households or industry. Due to their high calorific value, after appropriate transformation, it is possible to use them in thermal processes. The raw materials used to produce alternative fuels are: plastics, wood, fabrics, paper, mineral fractions or composite materials. But fuel of this type is difficult to combine with other sources of fuels such as coal or biomass because of variable combustion temperatures or different volatile substances.

MBT plants combine mechanical separation of different waste types contained in MSW with the biological stabilization of organic matter via processes such as anaerobic digestion or composting. The aim of these processes is to separate the biodegradable fraction of waste, as well as to recover recyclables from mixed waste streams. MBT can recover a large percentage of recyclables from mixed waste streams, in a way that supplements waste source separation. MBT technology has been widely applied in several regions around the world, especially in Europe. From 1990 to 2010, approximately 180 MBT plants were installed in Europe to divert biodegradable waste from landfills.

The main technological trend in waste management sector is a complex separate collections system implementation. However, in many countries the biggest problem is a low level of public awareness regarding segregation-at-source. People usually don't have conditions (or motivation) to collect waste separately to several different fractions - especially in big cities. There is a need to develop special technologies and methods, that will effectively treat mixed waste produced in households.

Many countries have already realized how costly a selective collection of waste at source is. In search of other methods, some countries are turning their attention to the mechanical heat treatment technology (MHT). The quality of secondary raw materials obtained in this process is more attractive to the final consumer. Moreover, the levels of recycling for the four fractions of waste, such as: paper, metals, plastics and glass, are high and significantly exceed the factors achieved in the process of mechanical and biological treatment. The new innovative technology MHT has been implemented in the first MHT facility by our case company Bioelektra in Poland. It is designed to treat unsegregated waste but works well also with separate collection systems. Waste is sterilized in autoclaves in high temperature and high pressure, which kills all the microorganisms in waste and makes it odourless. Then sterilized waste is separated into usable fractions of different secondary raw materials, biomass and RDF.

### 2.2.7 Customer needs

In the European Union there is a legal obligation for municipalities to provide sanitation services at cost recovery prices to their citizens. While dealing with certain forms of waste is the regulated responsibility of those who produce it, ensuring the recovery or disposal of household waste is the responsibility of municipalities. Local authorities need to find effective ways to involve communities



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

in waste collection and decision-making process concerning municipal waste facilities. The technical expertise to produce cost-effective and environmentally sound solutions in the waste collection no longer provides enough justification to approve waste facilities. Defining long-term infrastructure in the context of demographics, housing stock, consumer products, environmental knowledge and attitudes, as well as seasonal variations all have significant influence. At the same time predicting changes in national and European legislation and market conditions makes long term planning challenging.

From 1st July 2017 in Poland, new rules for segregation of municipal waste were applied. Now to four fractions of paper, metal, plastics and glass is added another one – biodegradable waste. Paper will be stored in blue containers, glass in green containers or bags (with the possibility of separation into clear glass – a white container will be used for it and a green container will be used for coloured glass). The yellow container is intended for metal and plastic waste, while the brown container will store biodegradable waste.

It is well known that the participation of residents in waste collection and separation is of critical importance for waste management system. There are research programs investigating the key influencing factors of pro-environmental behaviour of residents, their motivation and expectations, internal and external. Financial incentives and the cost structure are important, but some moral obligations also can have an influence. Perceived moral obligations indicate that the responsibility motivates people to be environmentally-friendly at different levels, especially within the household.

A key solution to the changes in customer perception and participation in the waste management system, especially in terms of management and reduction of the amount of waste stored is innovation. Thanks to innovative methods implemented in companies operating as recovery organizations as well as in companies producing waste, it is possible to reduce and reuse of waste and change it into another form and save resources. Processed waste can continue to be used as materials in the manufacturing process or energy recovery at the site of production or used in other companies. One of the barriers here is that customers are not ready enough to buy products made of recyclates.

### 2.2.8 Uncertainties

Given that the application of the waste legislation depends on the notion of “waste”, it is essential to define its scope. The Waste Framework Directive (WFD) encompasses a broad notion of waste defining it as “any substance or object which the holder discards or intends or is required to discard”, what can be criticise. There is a possibility of removing substances from the legal classification of waste reclassifying them as by-products at EU and national levels. When no end-of-waste criteria are set at EU level, member states may decide case by case whether certain waste has ceased to be waste considering the applicable case law. Certain specified waste would cease to be waste when it has undergone a recovery operation, including recycling, and complies with the generic requirements and the specific criteria defined for each waste stream.

Given that “waste” can be regarded as a resource, in some cases food-waste, biomass or other types of end-of-waste products cannot be used and re-used. Therefore, further harmonisation at EU level is required, especially in the context of setting well-defined criteria for the “end-of-waste” status and the calculation rules.

This means that some materials in certain countries can be regarded as “waste” but in others they can escape the waste regulatory requirements due to attribution to “end-of-waste” status. It is the big challenge for innovative technologies in the waste management, like MHT. There are no established, harmonised at the EU level provisions concerning the criteria for granting an end-of-waste status for



This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 730378

specific waste streams. Those inconsistencies in different EU countries may lead to fragmentation of the internal European market.

# 3 Business model assessment

The business model assessment has been conducted through a combination of publicly available information, interviews with managers, employees and stakeholders of the case organisation and internal documents provided by the organisation.

The objectives were to gain a deeper understanding of the circular business model and to map out the value chain and interactions in more detail to enable an analysis of the strengths and weaknesses as well as to consider the replicability and transferability of such a model to other entities and sectors.

## 3.1 The Bioelektra business model

### 3.1.1 Business model overview

The core business of Bioelektra is the municipal solid waste management. Business model includes very high level of recycling - up to 96% instead of 50-60% in traditional MBT technology - and almost zero waste to landfill.


*Source: Bioelektra*

The customers of Bioelektra are suppliers of waste, usually local authorities responsible for waste management systems. The receivers of sorted out secondary raw materials and other fractions are recyclers and end customers (end users). Moreover, Bioelektra Group cooperates with local authorities, enterprises and organizations engaged in waste management and seeking more effective solutions for waste treatment. Bioelektra works in partnership with institutes and research bodies, interested in further technology development. Regarding operational scale, the group of stakeholders embraces: waste suppliers (mostly municipalities, but also treatment plants, other waste holders) and the receivers of waste fractions after MHT technology process (recyclers and end customers).



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

The activity of the company is based on a highly innovative technology of mechanical-heat waste treatment (MHT) called RotoSteril. Waste is sterilized in RotoSteril BEG 7000 machines at high temperature and pressure, which kills all microorganisms in waste and makes it odourless. Subsequently sterilized waste is sorted into usable fractions of different secondary raw materials, organic fraction and RDF. These fractions can be further used to other processes and products. Usually these fractions are sold to recyclers.

The most significant fraction for circular economy obtained during MHT process is the organic mass. RotoSteril is now the only technology that separates clean organic fraction from unsegregated waste. It already fulfils the requirements for fertilizer, however Bioelektra constantly works on improving the quality of biomass. This fraction nowadays can be used at least in 4 ways:

1) as local renewable source of energy – as a product for biomass power plant or as an additional energy source in the process of cofiring. The biomass meets all the required emission legal standards.
2) as fertilizer, soil enhancer – but only for crops not for food purposes (e.g. lawns near motorways, golf courses etc.). The organic fraction can be also enriched with nitrogen or phosphorus compounds and serves as a basis for production of other fertilizers.
3) as a source of energy in process of bio-gasification. Moreover, gasification residues can be treated as compost (for example in France).
4) as an addition to construction materials – e.g. as a concrete filler or a main component of ecological bricks.

The process of mechanical heat waste treatment allows the production of homogenic organic fraction despite of input waste morphological diversity between different countries. Relatively high level of standardization of the obtained organic fraction is one of the advantages of Bioelektra's RotoSteril technology. Standardization allows the organic fraction to be used for various applications in different countries using identical technologies.

### 3.1.2 Business Model Canvas

Bioelektra created a waste treatment technology that unveils resource potential in waste. It allows for simple methods of waste collection and does not require segregation-at-source. The technology respects local community by making waste odourless. It is also the most financially viable waste treatment technology, as municipal solid waste is sterilised and turned into resources. It creates new opportunities for local economies in different parts of the world by delivering streams of recycled resources to the market by achieving a diversion rate of over 96% from landfill and creating:

- biomass which can be used as a fuel for heat and power plant, clean energy production,
- RDF which can be used in cement kilns,
- metals which can be used for aluminium and steel production,
- glass which can be used for packaging and glass wool production,
- plastics which can be used for packaging, diesel oil production and composite production,
- paper which can be used directly in paper mills.

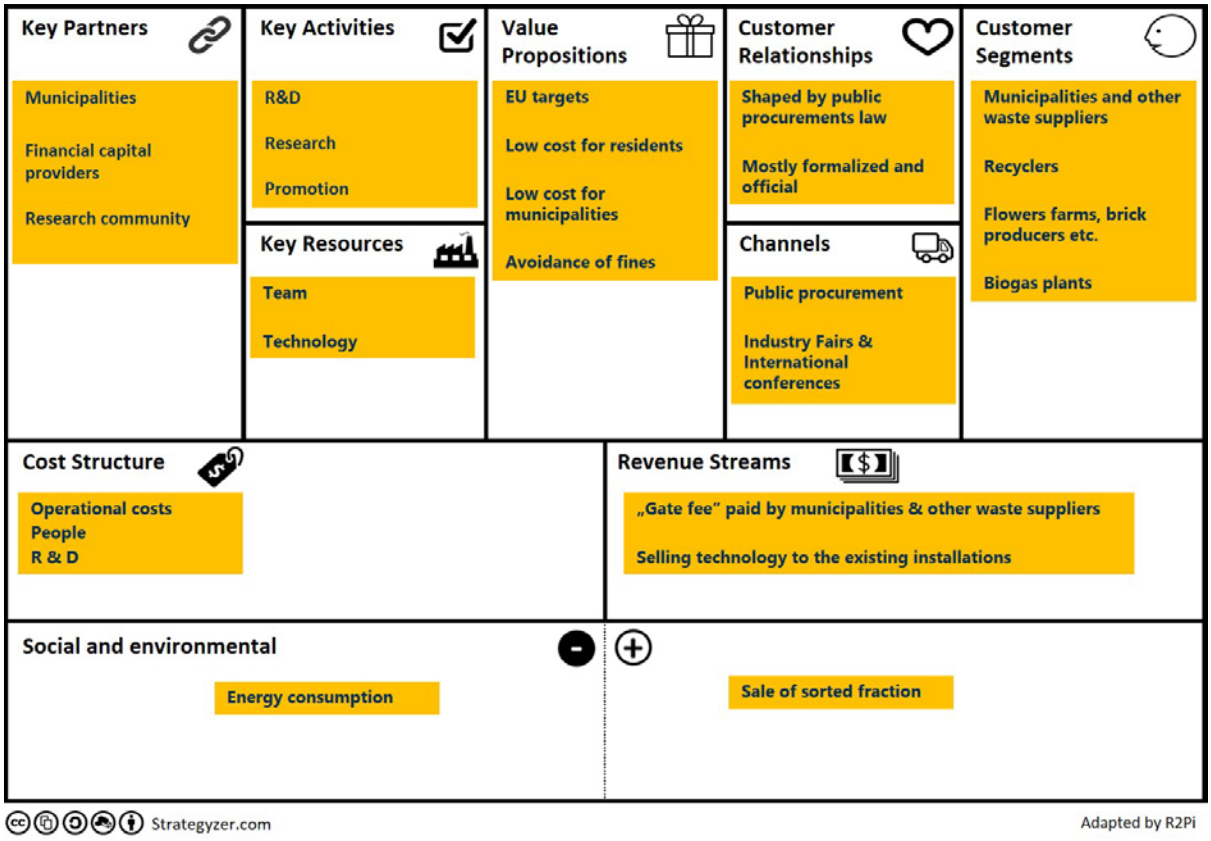
Bioelektra Group has a flexible approach ranging from technology supply to direct investment. Bioelektra delivers a complete custom-made facility according to local waste morphology. The company can be a co-investor with: a private, local operator; a local government, also in the Public-Private-Partnership structure; an experienced investor/ industry player from waste or energy sector.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Figure 5 shows the visual representation of Bioelektra's business model, based on the Business Model Canvas. This is to incorporate the way in which: (i) the value proposition and customer needs assessment and; (ii) circular economy principles, are applied and embedded. Each building block of the business model is described next:

*FIGURE 5. BUSINESS MODEL CANVAS*




*Source: own research*

**Customer Segments**

The main service of Bioelektra is municipal solid waste management. Thus, customers are the entities responsible for municipal waste management systems. In the EU legal framework this function is realized by municipalities which award public procurement. In the Polish legal system municipalities are the only "owners" of municipal waste. Municipalities charge fees to inhabitants. Funds from these fees are designated to finance local waste management systems. Bioelektra as the owner of MHT technology cooperates with municipalities in many forms. Bioelektra can be an investor, co-investor, operator, supplier of the technology.

Cooperation with municipalities can be carried out in two stages 1) investment phase: building own recycling plant or licensing the own technology for an existing plant that undergoes modernization - Bioelektra as investor, co-investor or supplier of the technology; 2) operating phase: processing of waste in own recycling plant, e.g. RIPOK Rozanki in northern Poland - Bioelektra as an operator of the plant.

Building a completely new installation is difficult under the existing regulatory framework in Poland. The main opportunities of development are to sell the technology to existing plants when they are to be modernized. In fact, each company operating a regional installation of waste treatment in Poland



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

can be a customer for Bioelektra, because it can use its MHT technology of municipal waste treatment. Due to the regionalization of waste management in Poland, a company that buys Bioelektra's technology in one region, at the same time in another region may be a direct competitor to Bioelektra's own installation.

There's no specific client segmentation for Bioelektra. Each municipality as the owner of municipal solid waste stream can be a potential client. Alternatively, potentially every operator/owner of a regional installation may be interested in buying Bioelektra's technology which provides technological and financial advantages.

The other group of customers of Bioelektra are the recipients of products after waste treatment processes - recyclates. These clients are also typical for companies operating facilities based on MBT technology. This is because most products of waste treatment - especially secondary raw materials - are identical to MBT and MHT technologies. The main differences between MHT and MBT technologies lie primarily in the quality and quantity of secondary raw materials obtained and the quality of organic fraction - odourless, cleaner, ready to use as fertilizer and biomass, and possible to obtain also from mixed municipal waste stream.

There are the following groups of recipients of organic fraction obtained during the MHT process:

- power plants: biomass power plants using biomass as a source of energy and traditional power plants using biomass in the process of cofiring,
- municipalities, sports clubs, highway operators etc. – using organic fraction as fertilizer or soil enhancer to grasslands. The organic fraction can be used as such, directly in the form obtained by Bioelektra. The other recipients of soil enhancer are cultivators of flowers. The organic fraction is not allowed to be used for agricultural land, e.g. for lands used to produce food.
- biogas plants – using organic fraction/biomass as a source of energy in the process of bio-gasification,
- brick manufacturers – using organic fraction as a concrete filler or component of bricks.

In all examples mentioned above, the organic fraction could be used directly, just after the MHT by Bioelektra. Major and relatively local recipients of organic fraction are preferable because of two factors:

1) selling to smaller clients requires the process of packing organic fraction which increases costs and reduces net margins,
2) the relationship between marginal profit for 1 tonne of organic fraction and the cost of transport. Organic fraction is relatively heavy. A distance up to 300 km is economically rational.

**Value Proposition**

The fundamental value delivered by Bioelektra is its new approach to waste based on the mechanical heat waste treatment technology (MHT) called RotoSteril. This technology until recently was widely used only for medical waste. Bioelektra has developed and utilized this technology for municipal solid waste. Bioelektra's technology recovers up to 96% of municipal solid waste with no need of separate collection. Moreover, RotoSteril is now the only technology that separates clean organic fraction from unsegregated waste.

Bioelektra's technology adds certain values compared to traditional (MBT) technology of municipal waste treatment:

1) Environmental
    - odourless process of waste treatment
    - levels of recycled output – up to 96%
    - almost zero-waste landfill – which is significant for local communities



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

- very low usage of water
- reduced emissions of greenhouse gases into the atmosphere in the future, mostly due to zero waste landfill.

2) Economic
   - lower costs for municipalities for waste treatment services: MHT installations are less expensive than MBT installations regarding capital expenditures and operating costs
   - avoidance of fines for breaking recycling and biodegradable waste to landfill targets required in all EU countries
   - obtaining clean organic fraction from collected mixed waste, and therefore lowering waste collection costs (this selective collection is not necessary technologically)
   - organic fraction – ready to use as final products for end consumers (soil enhancers, biomass for burning, additives for building materials) without additional costs
   - short investment implementation time frames - up to 9 months, assuming building permit approval.
3) Social
   - improved quality of workplaces compared to MBT technology
   - high level of recycling at low economic costs for residents
   - odourless processes of waste treatment – these processes are not burdensome to the neighbourhood residents
   - negligible zero-waste to landfill – according to various studies in Poland local communities are the strongest opponents of landfill sites, which causes new landfill sites construction very difficult.

The circular economy business model for MHT facility utilizing RotoSteril technology includes a very high level of recycling - up to 96% instead of 50-60% using traditional MBT technology. This highly innovative technology enables lower "gate fee" for municipalities and finally for residents, high revenue from fractions (e.g. secondary raw materials, organic fraction as a biomass, fertilizers etc.) sales, and minimal level of landfill tax (in Poland labelled as "Marshal's fee") embracing less than 10% of waste. Additionally, there is low employment level needed and simultaneously high level of process automatization.

In contrast, MBT technologies-based business models assume a high "gate fee" needed to cover high landfill taxes - embracing even over 70% of waste - and high employment, because people should work at manual segregation stands. The other advantage of Bioelektra technology is that it can be used to unsegregated waste, which finally lowers the cost of collecting municipal waste - selective collection is much more expensive than nonselective.

Water utilized for the sterilization process is used in a closed circuit with minimal loss. It is mainly used for cleaning gas tanks and gas for steam production. The average water consumption is about 70 $dm^3$ per 1 tonne of waste.

**Channels**

Bioelektra marketing activities are focused on the developing markets, such as the Middle East, Russia, Asia, Africa. In these growing markets there are many waste management issues and problems that need to be solved for a range of reasons: environmental, social and economic. Bioelektra's solution is received with a positive response, as it requires little or no segregation at source, lowering costs and meeting expectations of societies. Environmental benefits play a certain role; however, it seems that economic factor to choose Bioelektra technology is the key motivator.

The United States is the single most promising market with a relatively low "gate fee" level and is clearly underdeveloped in terms of technologies in use. The dual system which prevails in the US causes 70% of waste to be landfilled. Bioelektra's goal is to close the circle with clusters producing



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

electricity, heat for the waste sterilization, plastic-processing plants and if feasible, aluminium smelters.

The main customer of Bioelektra are municipalities which are responsible for waste management systems on the local level. The relationships between Bioelektra and these crucial customers are shaped primarily by public procurement laws in different countries.

In Poland's case, each municipality must select a company responsible for municipal waste gathering and collection as well as treatment. The company must be chosen in accordance with public procurement law. It is worth mentioning that the selection of the installation responsible for waste treatment (named in Polish law "RIPOK" – regional installation of municipal waste treatment) is strongly regulated by province laws (province waste management plans). The plan delimits boundaries of waste treatment regions within a given province. The number of RIPOK is limited within one region and no business can fund RIPOK which is not listed in the province plan.


*Source: Bioelektra*

**Customer Relationship**

The relationships with municipalities are mostly formalized and official. The potential for collaboration and building new relationships result also from public events, conferences etc. Public events give the company opportunities to promote its own solution, primarily RotoSteril technology. Alternatively, Bioelektra competes in public procurement, which provides opportunities to present its service and technology.

The main products for customers are recyclables. Bioelektra technology retrieves over 90% of all recyclables contained in waste, regardless of the morphology - waste composition. The fractions after the process are odourless, safe to work with, dry and storable. Any fraction can be segregated, including PVC, so the fuels biomass and pre-RDF are chlorine-free. Fractions segregated currently are: PET, PP, PE, PS, glass, ferrous metals, non-ferrous metals, pre- RDF light (paper and films), pre-RDF heavy (textiles, rubber, wood), biomass and 3D (landfilled fraction). Glass is on average 96% quality, clean and can be separated by colours if the project requires. The quality can be improved to 99%+ glass content with new separator. PET, PP, metals are sold directly to the recyclers.

For projects with waste streams 300 000 tonnes/year upwards Bioelektra recommends building plastic processing unit to produce PET and PP flakes to maximize profits and margins and become



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

independent from local recyclers. Pre-RDF can be easily transformed into full RDF. It can be also used in the modern boilers (mix fuels) or modern cement kilns accepting 14 GJ/t CV RDF fuels. The biomass after Bioelektra process has several uses: a. alternative (green) fuel of calorific value 12 GJ/t up to 16 GJ/t (post process and dry state); b. fertilizer / soil enhancer; c. resource for bio-gasification; d. resource for building materials production – bricks and light aggregate; e. hydrogen production – positive lab tests at the Mazurian University in Poland; f. potential for the bioplastics/biofuels production.

**Revenue Streams**

The revenue of Bioelektra comes from two operational activities:

- "gate fee" paid by municipalities and other waste suppliers – rate per 1 tonne of waste brought to the recycling plant,
- sale of sorted fraction, i.e. secondary raw materials, RDF and organic fraction for different purposes (primary biomass or a fertilizer).

The structure of revenue stream depends on many factors in various countries. Thanks to the recycling rate up to 96%, income stream when using Bioelektra's technology is higher and payback time shorter. The sorted fraction sale is bigger, the "gate fee" charged to waste owners, i.e. municipalities – can be lower. However, the obtained fraction sales opportunities are strongly conditioned by the regulatory framework of a certain country. Generally, the secondary raw materials markets are global, and prices are relatively similar in different countries. Thus, revenue stream can be similar in different countries. Its value depends mainly on the composition of the municipal solid waste stream, its morphology.

The main source of revenue differentiation of Bioelektra installation is the legal status of organic fraction obtained during MHT processes in Biolektra's technology. The more possibilities of using the organic fraction in certain country, the bigger its sale, the necessary fee from municipalities become lower. In the case of city D., the opportunity to sale organic fraction as fertilizer or biomass allows to lower gate fee to 30 EUR/tonne. At the same time, the estimated gate fee in city B. is 83 EUR/tonne.[i]

When there's no possibility to sale organic fraction in the country, it becomes a problem for Bioelektra and it can generate additional costs. This is the Poland's case, where Bioelektra must pay around 20 EUR/tonne for the collection of organic fractions by external companies. Subsequently this fraction is being landfilled what generates additional costs in the waste management system.

| | City B. | | City D. | |
|---|---|---|---|---|
| **Revenues from sales** | | **18 280** | **0** | **15 898** |
| Receipt of waste | 79,85% | 14 597 | 57,51% | 9 143 |
| Volume (k tons) | | 175 | | 300 |
| Price (EUR/t) (gate fee) | | 83 | | 30 |
| Sale of fractions | 20,15% | 3 683 | 42,49% | 6 755 |
| Water | | 0 | | 0 |
| Biomass | | 0 | | 1 524 |
| Iron | | 298 | | 429 |
| Aluminium | | 2 088 | | 257 |
| Minerals/stones | | 0 | | 0 |

[i] However, the sale of pre-RDF is not assumed.



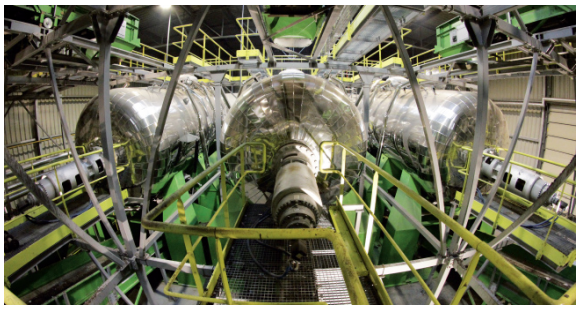
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

| | | | | |
|---|---|---|---|---|
| Textiles (pre-RDF) | | 0 | | 1 860 |
| Glass | | 24 | | 0 |
| PET clear | | 398 | | 857 |
| PET blue + green | | 398 | | 857 |
| PP (polypropylene) | | 477 | | 971 |
| PE, PS | | 0 | | 0 |
| Volume (k tons) | | 175 | | 300 |
| Water | 16,30% | 29 | 11,67% | 35 |
| Biomass | 24,40% | 43 | 25,33% | 76 |
| Iron | 1,50% | 3 | 1,33% | 4 |
| Aluminium | 1,50% | 3 | 0,00% | 0 |
| Minerals/stones | 9,70% | 17 | 13,67% | 41 |
| Textiles (pre-RDF) | 24,60% | 43 | 31,00% | 93 |
| Glass | 3,00% | 5 | 3,00% | 9 |
| PET clear | 2,50% | 4 | 3,00% | 9 |
| PET blue + green | 2,50% | 4 | 3,00% | 9 |
| PP (polypropylene) | 3,00% | 5 | 3,33% | 10 |
| PE, PS | 10,00% | 18 | 1,33% | 4 |

*Source: Bioelektra internal document*

**Key Resources**

Main resource of Bioelektra business come from its MHT technology of waste treatment. The physical outcome of the process is typical for waste management facilities (mechanical biological treatment) but process of Bioelektra is much more effective than traditional methods (MBT). Technology is based on sterilization of waste in own-design autoclaves and automated segregation of all fractions contained in waste. Sterilization process takes place in conditions of 130°C and 3 bars pressure. The system uses moisture (water) contained in waste for the sterilization purposes. This allows for drying the waste and decrease of the weight by 17% and volume by 60%. Thanks to sterilization, the $CO_2$ and $CH_4$ emissions are stopped, the waste becomes odourless, safe for humans and environment, dry and easy to be processed.



*Source: Bioelektra*

The technology can accept any kind of municipal waste – unsegregated, segregated (organic or dry), green waste (up to 20%). The software will recognize the composition of waste and apply conditions of the sterilization process – time, pressure and temperature accordingly. It has been positively tested for landfill mining – cleaning old landfills. The whole process is managed by the software of the AI qualities, based on fuzzy logic. This allows to decrease the number of employees. Around 8 persons work on 1 shift at the 100 000 tonnes a year processing plant.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

The automated segregation process allows for the 90+ retrieval rate. It can separate the following fractions: plastics split by PET, PP, PE, PS, PVC, ferrous and non-ferrous metals, glass (also split by colours). Additionally, Bioelektra can capture most of the vapour from waste and turn it back into the clean, fully re-usable water. This also means that the Bioelektra plant can have neutral or positive water balance.


*Source: Bioelektra*

The technology allows to separate the biodegradable fraction in the form of the biomass of unique quality, clean, sterile, storable. The bio content is 90%+, no hazardous substances, heavy metals, etc. The technology is fully scalable to the size of the waste stream and can be adjusted up and down in scale during its operations by adding or taking out autoclaves. Autoclaves are easy to transport (no special permit required) and installation is fast. The construction time is 9 – 12 months since receiving all the permits. Most of the investment cost is machinery and equipment which makes it ideal for external financing (bank or leasing). The construction costs are usually 10-20% of the total CAPEX. Technology is 100% environmentally friendly – it is odourless, there is no leakage, fumes and sewage system needed thus public acceptance and support can be expected.

Bioelektra's technology is scientifically verified, patented and tested in practice. MHT technology is the first Polish technology notified to BAT conclusions in the field of waste management. The technology was reported as: 7. Sterilization and high temperature pressure of mixed municipal solid waste. Emerging techniques - subsection 7.2.3. Mechanical treatment of waste with calorific value or 7.4 Physico-chemical treatments. In the final version of the BREF reference document, the records regarding autoclaving have been included in Chapter 4 - Biological treatment of waste, 4.4. Mechanical biological treatment (MBT), 4.4.1. Applied processes and techniques.

The technology is constantly under improvement. Currently Bioelektra turn about 25% of waste into alternative fuel, but research probably will enable recovering even more materials for recycling.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Research on separation of cellulose for the industry and use of some fractions in construction industry is conducted.

An important asset of the company is also the managerial staff who have extensive experience in the waste industry, and the working team.

**Key Activities**

- Conducting waste treatment installations based on own technologies,
- selling the technology to the existing installations operated by private or municipal companies,
- conducting promotional activities regarding the benefits of implementing MHT-based technology,
- cooperation with research centres and conducting own R&D works in the field of technology development.

**Key Partners**

- Local authorities – responsible for waste management systems; in Poland this function is realized by municipalities,
- key partners at the local level – i.e. recyclers, power plants, biogas plants, brick manufacturers, etc.

**Cost structure**

The business model is cost-driven thanks to very innovative technology. The mechanical heat treatment technology used by Bioelektra is currently the most cost-effective waste treatment technology available in the market. An average cost of waste processing using Bioelektra technology is estimated at 15-37 Eur/tonne (depending on country). These costs include labour, electricity, gas, insurance, waste utilization, but not include depreciation. The main cost is the cost of energy used in the sterilization process as well as the cost of salaries. Both the costs of energy consumption and wages are strongly different at the level of individual countries.

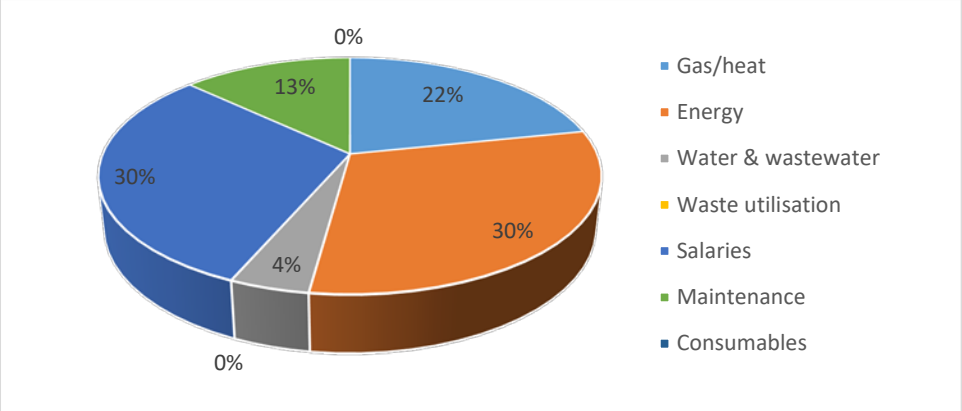
Bioelektra's technology allows to avoid penalties both for failing to meet the limits of recycling and exceeding the weight of waste for landfill in EU countries. In these countries cost of waste processing in MHT technology extends from 26 EUR/tonne (Athens, Greece) to 37 EUR/tonne (Hague, Holland). In case of European countries, the share of energy and gas/heat costs is estimated at 35% (Bratislava, Slovakia) up to 50% (Athens, Greece) of total costs without depreciation. At the same time the share of salary costs is about 30% (Bratislava, Slovakia) up to 50% (Hague, Holland).

The annual depreciation in the case of MHT installation is comparable to MBT installation with similar processing capacity or even lower. It is caused mostly by costs of autoclaves and different separators used for sorting waste. The capital expenditures per 1 tonne of processing capacity of installation is estimated between 310 and 370 EUR. However, regarding that traditional MBT technology requires bigger landfill sites, the overall process of functioning of waste management system based on MHT technology is much less expensive. One of crucial elements of cost advantage of the entire system based on MHT technology is waste collection system. The MHT technology does not require selective collection, which is much more expensive than nonselective collection.

Below is an example of costs structure for an installation with a processing capacity of 150,000 tonnes (project in city D.).



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378




*Source: Bioelektra internal document*

It is worth mentioning that especially in EU countries Bioelektra's technology is highly competitive. For example, all regional installations in Poland use traditional, mechanical biological treatment technology. An average cost of waste processing in this technology is around 60-80 EUR/tonne. It gives Bioelektra huge advantage to propose significant lower gate fee for municipalities than its competitors.

**Environmental/social costs and benefits**

The environmental cost in this case is energy consumption. Indirect costs are connected to the coal-based energy sector in Poland with the high level of CO2 emission.

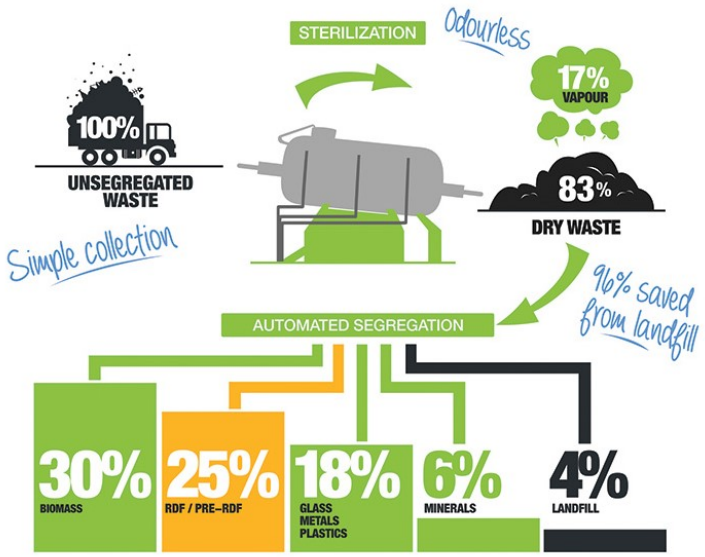
The main Bioelektra' products for customers are recyclables – it brings environmental benefits from the waste management, comparing with landfill. The level of environmental benefits is lower in case of delivering products for biogas plants. The most promising environmental benefit in the case of Bioelektra technology is almost zero-waste landfill which is at the same time the significant social benefit for the local community.

### 3.1.3 The Value Network

The value network created through the circular business model of Bioelektra is shown in Figure 6. The value network is made of several stakeholders, which are located either upstream or downstream Bioelektra. The network is highly dependent on the local conditions, so here is presented only in the general form. The waste stream is delivered by municipality, and recyclates are taken by different commercial partners.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

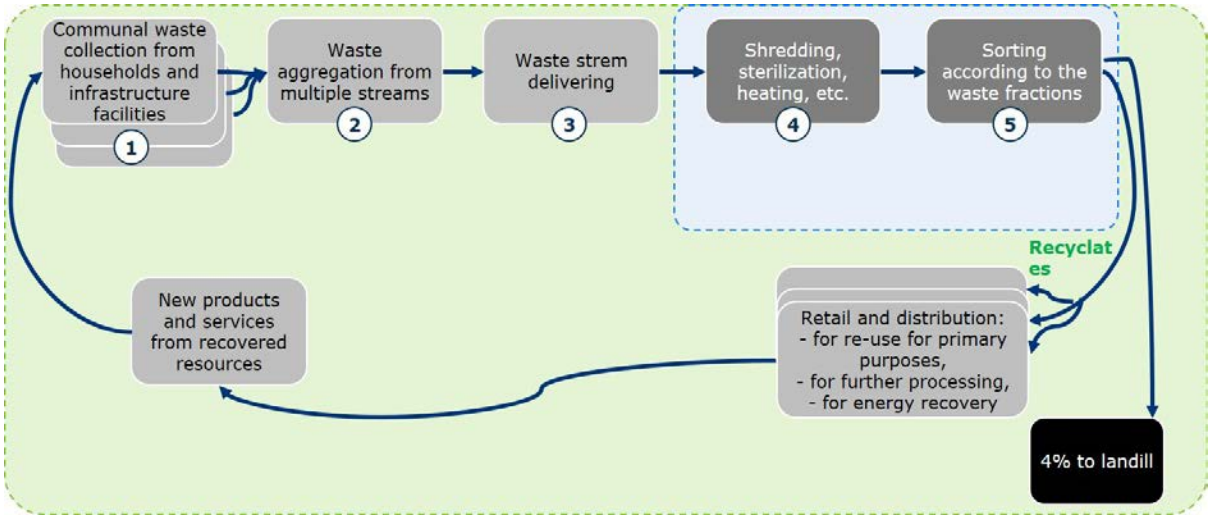



*Source: Bioelektra*

### 3.1.3.1 Material Flow

Overall, Bioelektra's business goal is to provide several 1 million tonnes processing capacity units world-wide. This represents an overall goal of achieving 10 million tonnes waste processed using Bioelektra's technology over a period of 5 to 10 years. 10 million tonnes represent 1% of OECD countries waste production as of today. Figure 6 show the material flow of waste that is managed by Bioelektra.

*FIGURE 6. THE MATERIAL FLOW*




*SOURCE: OWN ELABORATION*

Municipal waste stream is directed to the installation after the collection - separate or non-separate. Municipal waste is defined as waste generated by households, as well as waste not containing hazardous components, generated by other waste producers, which, because of its nature or



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

composition, is like waste from households. The main sources of municipal waste are households and infrastructure facilities (trade, services, crafts, education, the social part of industry and others). The waste is characterized by high variability due to: location, time of year (seasonality), religious denomination (holidays celebrated), culture, level of living standards of the inhabitants, ecological awareness, used collection and transport system, etc. Also sieve and under-sieve fractions after MBP processes can be treated effectively with MHT technology.

After being brought to the installation waste is subjected to certain processes. The overall process starts from shredding waste to homogenise it to a particle size of 500 mm. From the preliminary shredder it is transported to the pressure vessel where the sterilization process starts. Waste is heated to evaporate water and to sterilize it. The sterilization has an impact on stabilization and effectiveness of the recovery of raw and other materials which make up the mixed municipal waste. If these two targets are met, the level of recovery of substances and materials can be maintained at an efficiency level of up to 96%, including 17% of water. The waste from the sterilization process has a changed structure and physicochemical properties.

Reducing moisture and the volume of hydrated composition of waste, including the organic fraction, directly affects the increase in bulk density of sterilized waste, which is one of the factors determining the choice of capacity/size of machinery (cubic capacity). After process of sterilization waste comes to the sorting processes using traditional methods, like cascade screens and then respectively mechanical, ballistic, optoelectronic separators depending on the type of waste fraction after cascade screens.

#### 3.1.3.2 Value Flow

Main input is waste stream and main outputs are recyclates, which are the main products of Bioelektra. The following materials and resources, including secondary raw materials, are obtained from waste sorting (after heating treatment in autoclaves): metals, non-ferrous metals, organic fraction/ biomass, glass cutlet, PET, PVC, cellulose fraction, textile fraction, mineral fraction. The share of individual sorted factions depends on the composition of municipal solid waste stream (e. g. the morphology of waste) brought to recycling plant. The morphology of municipal solid waste varies, depending on geographic location, building structure, population habits, consumption patterns, etc. The simulations from two planned projects for waste morphology in city B. and in city D. are presented below.

| Fractions sorted out | B. | D. |
|---|---|---|
| Water | 16,30% | 12,07% |
| Biomass | 24,40% | 26,21% |
| Iron | 1,50% | 1,38% |
| Aluminium | 1,50% | 0,00% |
| Minerals/stones | 9,70% | 14,14% |
| Textiles (pre-RDF) | 24,60% | 32,07% |
| Glass | 3,00% | 3,10% |
| PET clear | 2,50% | 3,10% |
| PET blue + green | 2,50% | 3,10% |
| PP (polypropylene) | 3,00% | 3,45% |
| PE, PS | 10,00% | 1,38% |

*Source: Bioelektra internal document*

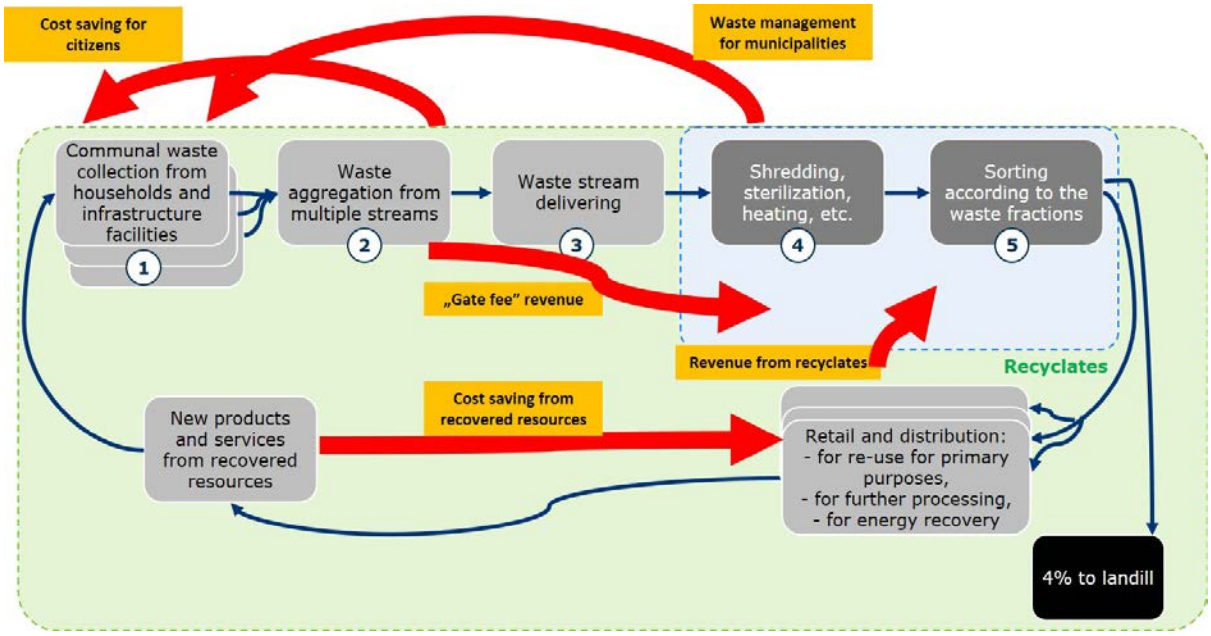


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

The recycled products can be used in various ways:

- for energy recovery – cellulose fraction, textile fraction, biomass;
- for re-use for primary purposes – metals, non-ferrous metals, glass cutlet, PET, PVC, cellulose fraction, textile fraction;
- for further processing for other than primary purposes – organic fraction/ biomass, glass cutlet, PET, PVC, cellulose fraction, textile fraction.

*FIGURE 7. THE VALUE FLOW BIOELEKTRA*




*SOURCE: OWN ELABORATION*

## 3.2 Business model circularity assessment

In this section the business model that has been presented previously is assessed from a circularity point of view. The objective is to reveal strengths and weaknesses of the Bioelektra resource recovery business model, and to identify the business model opportunities and threats, based on the case study presented, literature and discussions with Bioelektra respondents. The assessment is based on a specific tool presented in the Appendix.

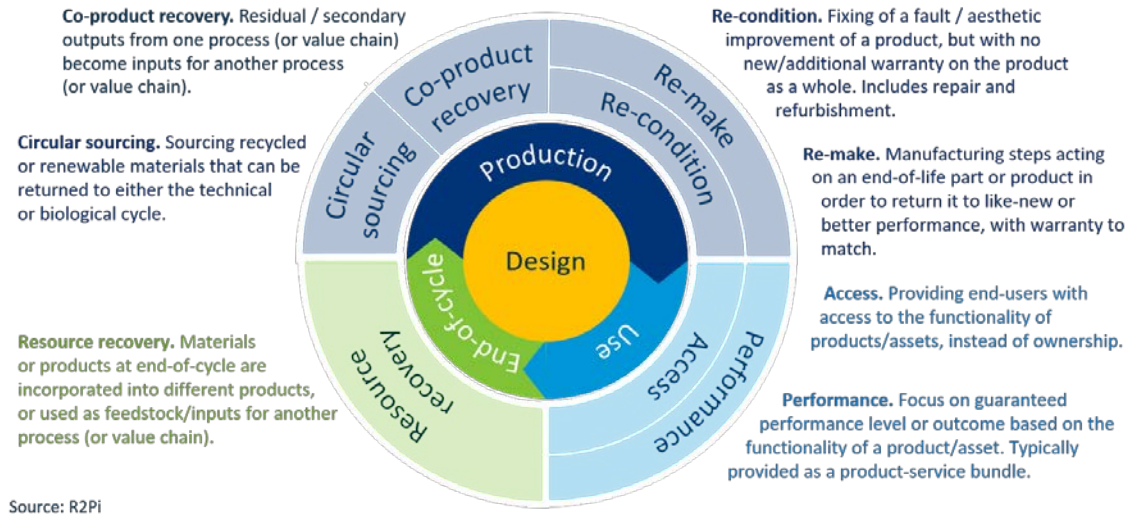
### 3.2.1 Circularity assessment

To understand circularity within Bioelektra business model, we use the circular business model patterns figure – CEBM (see below). This model presents the different steps of products life-cycle from production to consumption and end-of-life. It is presented in a circular way to illustrate the possibilities of creating circular business model by connecting products' end-of-life to the production of new products.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

*FIGURE 8. CIRCULAR BUSINESS MODEL PATTERNS*

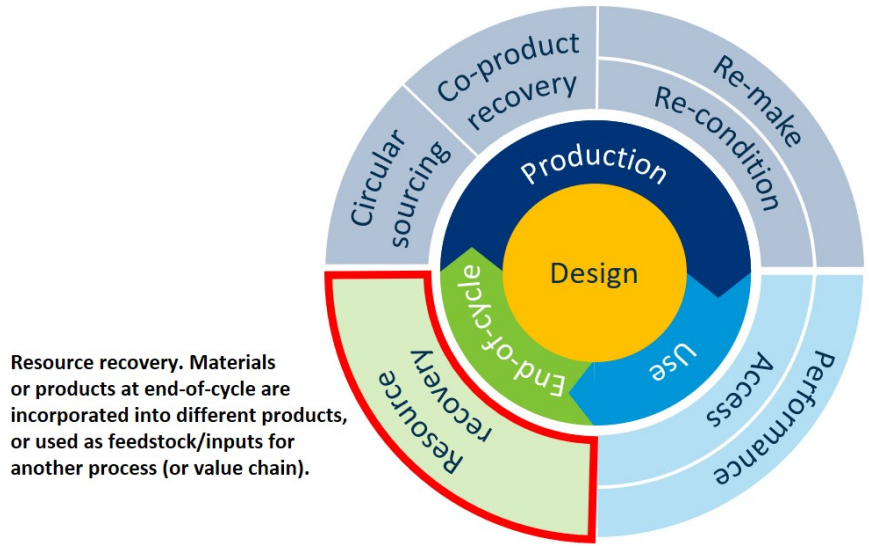



Traditionally, the waste management sector in the EU could be described as a "collect and dispose" operation: collecting mixed waste streams from municipal and commercial sources and disposing of the waste to landfill or through incineration. The waste management system in the circular economy will have to go beyond such an end-of-pipe approach to become an integral part of an economy, closely linked to patterns of production and consumption.

Circular product design will be based on the feedback from the waste management sector concerning the ways to remanufacture, dismantle and recycle. At the same time the waste management sector will become a partner in developing circular business models focused on waste prevention and turning waste into resources.

Resource recovery is the main circular economy business model pattern in the waste management of the future and this is the case of Bioelektra. New technology of waste treatment implemented by Bioelektra is allowing recovery of resources in the municipal waste stream.

*FIGURE 9. CIRCULAR BUSINESS MODEL FOR BIOELEKTRA*




*SOURCE: OWN ELABORATION*



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Municipal waste makes up less than 10 per cent of total waste generated in the EU, but it is one of the most polluting waste streams, with high potential for improvement. Activity of Bioelektra Group is based on the improving circular economy model since the very beginning. The aim of establishing the company was to implement and deliver the technology of waste treatment allowing recovery every material from waste. Bioelektra was focused on reducing the negative impact on the environment in waste management. The company was involved in the process that allow to obtain clean secondary raw materials and organic fraction, ideal for recycling purposes.

It has now the full control concerning the composition of final products – recyclates - that they obtain. Those products can circulate in the economy for longer. But Bioelektra is not a manufacturer, so real circularity is out of their business model. Bioelektra fulfils its own function towards the circularity of the economy by addressing some of the challenges, but they don't have complete control over their remanufactured products.

All stakeholders are convinced that there is a need in the future for close partnership between the waste industry and companies with a circular vision for their products. Main challenges relate to moving beyond the perception of "waste-as-a-problem" to "waste-as-a-resource". It is the crucial condition for a widespread growth in circular economy activities in Europe. Collecting high quality waste streams for recovery, re-use, remanufacturing and recycling requires not only appropriate technology and highly innovative commercial organizations but also citizen engagement and integrated infrastructure development from the municipal to the EU level. Short- term and long-term benefits will include reducing environmental burden as well as creating both high-skilled and low-skilled jobs for an inclusive, green economy.

### 3.2.2 Financial and non-financial outcomes assessment

An average cost of waste processing using Bioelektra technology is estimated at 15-37 Eur/tonne (depending on a country). These costs include labour, electricity, gas, insurance, waste utilization. The main cost is the cost of energy used in the sterilization process as well as the cost of salaries. Both the costs of energy consumption and wages are strongly different at the level of a country. The circular elements have contributed to the profitability of the company.

The revenue comes from two operational activities of Bioelektra: "gate fee" paid by municipalities or other waste suppliers and sale of sorted fraction, i.e. secondary raw materials, RDF and organic fraction for different purposes. The structure of the revenue stream depends on many factors in various countries.

It is difficult to assess non-financial outcomes from the secondary raw materials, but theoretically it can bring several economic, social and environmental benefits. The use of those materials additionally results in less carbon and other harmful substances emission. At this stage of development, the environmental and social outcomes are rather negligible due to the small size of the company operations.

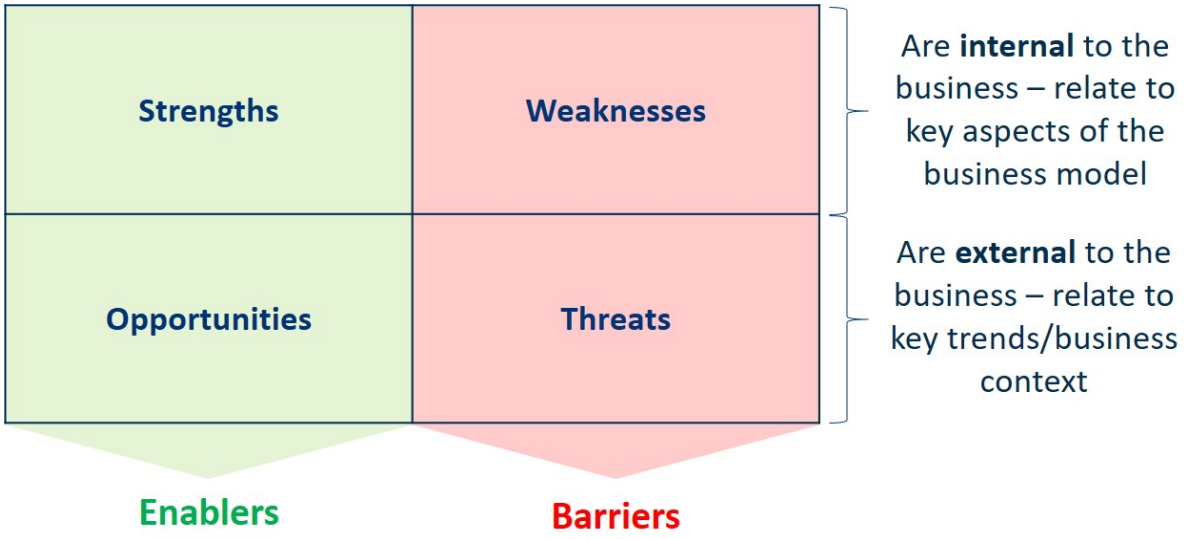
### 3.2.3 SWOT analysis

This section contains an analysis of the strengths, weaknesses, opportunities and threats (SWOT) associated with the circular business model of Bioelektra. The analysis of strengths and weaknesses is based on previously prepared questioner - see Appendix C. The assessment of opportunities and threats is based on business context assessment presented in Appendix A.

A SWOT is a basic matrix to give a useful overall, view of a company possible strategic orientation. It is composed of internal positive and negative dimensions (strengths and weakness, top of the matrix) and external positive and negative dimensions (opportunities and threats, bottom of the matrix).



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378




Source: R2Pi

Crucial for the business success of Bioelektra is the legal framework. Some provisions of EU law, especially in Directive on Waste, creates many opportunities for Bioelektra to expand. The constant increase of recycling level, which is declared by EU can create much bigger market for Bioelektra services. Limiting the biodegradable municipal waste going to landfills can create another possible opportunity, as well as a radical decrease in the amount of waste disposed in landfills, while increase of recycling and the recovery of waste.

All these legal requirements are easy to meet thanks to Bioelektra technology – which creates many possibilities for strategic development of the company. However, the regulatory framework is now the biggest threat for Bioelektra, especially different interpretation of the legal requirement in different countries.

The key opportunity for Bioelektra – presented by CEO of that company - is expansion into new markets. Very interesting from the point of view of the circular economy are the countries of the Middle East. The legal possibility of selling organic fraction obtained during MHT process as a fertilizer gives very high return rate to Bioelektra's projects in the Middle East markets. The demand for natural fertilizer at this region is relatively high and the company has the preliminary arrangements regarding receipts of organic fraction (about 15-20 EUR/tonne).

The company managers are presenting as a big opportunity for Bioelektra an intensive lobbying for changing the existing regulations in Poland. Particularly, Bioelektra's chance is to grant a legal status of biomass to the organic fraction obtained during the MHT process. Granting this status would allow legal burning of biomass or co-firing in Poland for energy recovery.

According to Bioelektra managers there is a necessity as well to start lobbying for compliance with existing EU law at the level of Poland. There is a ban on landfill a high calorific waste fraction over 6 GJ/Mg from 2016 in the Polish law. In practice, however, these provisions are not respected. The ban on landfill of this group of waste strictly designates of waste with 19 08 05, 19 08 12, 19 08 14 and 19 12 12 codes and all from group 20 codes. In practice, 19 12 12 waste - the most common one - are fictitiously subjected to composting. Thus, they obtain 19 05 03 code and are being landfilled.

Within Bioelektra Group, many initial activities are undertaken aimed at combining the construction of a waste treatment installation with biomass heat and power plant construction projects (biomass CHP – combined heat and power). The firing of biomass is financially much more effective way of waste treatment than firing mixed municipal solid waste stream. Especially, in Poland capital



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

expenditures for construction of 1 MW of energy are estimated at 2 million EUR for Bioelektra's power plant firing biomass and about 9,1 million EUR for incineration plant firing municipal solid waste (data for an existing incineration plant operated by ZUOK Bialystok in north east Poland).

More particularly, Bioelektra's CAPEX per $MW_e$ installed would be lower than on $MW_e$ installed in typical incineration plant and higher than on $MW_e$ installed in typical biomass fired CHP. Flue gases treatment installation would have to be extended but due to the lower level of Bioelektra's fuel (selected biomass) contamination in comparison to municipal solid waste, Bioelektra's CHP could comply with emission standards obligatory for incineration plant on lower CAPEX. In that case the calculation of CAPEX on flue gases treatment installation requires detailed analysis of Bioelektra's fuel.

*FIGURE 10. SWOT ANALYSIS FOR BIOELEKTRA*

| Strengths | Weaknesses |
|---|---|
| • Highly innovative technology enables lower "gate fee" for municipalities and finally for residents<br>• It does not require any additional upstream separation since sorting happens downstream<br>• High recycling rate achievable through RotoSteril technology | • High dependence of revenues from municipalities<br>• Sustainable value of the secondary raw materials for the customer is not yet captured<br>• Difficulties in attracting more commercial customers |
| **Opportunities** | **Threats** |
| • Expansion into Middle East markets - demand for natural fertilizer there is growing fast<br>• Landfilling ban and new targets for reuse and recycling in EU<br>• The same understanding of waste and acceptable practice across EU countries | • Waste management market is strongly regulated - but different interpretation in different countries<br>• The organic fraction obtained in the MHT technology can not become a commercial product – at least in the legal sense in Poland<br>• The advantages of company technology are almost completely eliminated by Polish law system and limited to effectiveness of mechanical sorting |

*SOURCE: OWN ELABORATION*

### 3.2.4 Final assessments

Waste management is an important part of transition into circular economy until we start living in the zero-waste world. The environmental benefits of avoiding waste clearly far exceed the environmental impacts of any other waste management options. The most pressing challenge for now is how to reduce level of waste generation, not only municipal waste, or at least to stabilize the stream. Municipal waste generation per capita is still increasing in around one-third of all EU Member States and while almost all of them have developed some policies toward prevention, promotion and awareness raising, it is not enough considering the overarching goals of a resource-efficient economy.

The growth of a circular economy will require high-quality, secondary raw materials that can be fed back into production processes. It should be possible that the waste management sector is delivering the main value of circular economy: turning waste into a resource. In this report some concrete proposals for changed regulations on waste treatments were discussed already. Without those changes it is impossible to expect positive impact from the waste management sector.

In the case of Bioelektra one can think on several possible - direct and indirect – positive impacts on a regional and a national scale. Bioelektra resources enable:

- immediately fulfil local, national or international requirements regarding waste management – MHT technology overreaches all implemented global policies;



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

- widely decrease the costs of local waste management systems – 1) it works with the same effectiveness of recycling regardless to non-selective or selective collection processes; 2) organic fraction obtained during the MHT process can be used directly as a biomass or fertilizer, regardless of whether the organic fraction was collected selectively or not;
- eliminate odours from waste to satisfy local communities;
- simplify local waste collection systems, which decrease costs of waste transportation, logistics, etc. and is more socially friendly;
- stimulate local recycling markets and industries, create new workplaces;
- increase economic competitiveness and innovation of regions;
- increase attractiveness of regions thanks to the usage of new innovative ecological technologies in environmental protection;
- reduce GHGs emissions and achieve goals related to climate policies.

In general, waste management system required in the EU countries present a clear orientation towards the circular economy. These aspects were discussed already in depth in the section on the analysis of the Bioelektra business model. The set of legal and regulatory conditions that apply to the waste management industry appears as the most influential framework for Bioelektra.

However, Bioelektra's CEO acknowledges difficulties due to the changes in the legal environment. Waste management services market is strongly regulated as well as on the EU level, national level and even province level (in Poland). According to the specific implementation of EU Directive on waste in Poland, the organic fraction after Bioelektra's MHT process officially is not the biomass or different products like natural fertilizer. This technology is not covered in the Polish legal system as allowing to reach the target of 96% of recycling. This case is one of elements of general Polish waste law dysfunctionality, which strictly defines the waste treatment technology but not the output/result of the technology.

The organic fraction is defined in terms of input. Organic fraction collected selectively loses the status of waste and after composting it can become a fertilizer. It is included in the stages of recovery and recycling of waste. The organic fraction obtained after MHT technology from mixed waste - not from organic fraction collected selectively - is not organic fraction in the legal sense and it cannot become a product: neither a fertilizer for agriculture nor a biomass for professional power industry. It can only be landfilled or burnt in a waste incineration plant what generates additional costs.

It is a paradox, considering that Bioelektra has scientific research confirming the effectiveness of RotoSteril technology. MHT technology is the first Polish technology notified to BAT conclusions in the field of waste management. According to the results of scientific research, organic fraction obtained from mixed waste is physically and organically identical to the biomass and in fact it can be also used as the natural fertilizer. Additionally, this organic fraction burning process meets the emission standards, especially criteria of greenhouse gases emissions.

Bioelektra's respondents also point to the fact that there are practical consequences of the Polish legal system for their business. The advantages of RotoSteril technology are almost eliminated by Polish law system and are limited only to higher effectiveness of mechanical sorting. Bioelektra must pay other companies for receiving organic fraction from plant in Rozanki in Poland.

At the same time in Poland neighbourhood countries like Slovakia, the organic fraction obtained during the process of MHT has the legal status of biomass. The biomass has the market value in Slovakia. It can be sold at about 30-40 EUR/tonne. The legal context in Slovakia gives the MHT technology huge competitive advantage over the traditional MBT technology. This legal problem is strictly related to the European regulation on municipal waste decoding. Each EU country determines its own decoding method and the Polish law on waste limits the Bioelektra development possibilities.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

The company's CEO also indicates that there is in Poland a strong support on the national and province level for thermal waste treatment plants (incinerators), although the incineration is the last wanted level of waste treatment at the waste hierarchy in the European Action Plan for the Circular Economy. A five-step hierarchy of waste management options should be promoted, from the most favoured: waste prevention, reuse, recycling, recovery including energy recovery, disposal. The support for incinerators in Poland is also related to the method of decoding.

Bioelektra's CEO is convinced that the regulatory environment in Poland is very unfavourable for this company approach, because in the long run it petrifies financial and environmentally fewer effective technologies of waste treatment. Moreover, Polish government co-finances the construction of incinerators and modernization of MBP installations from EU and national public funds. Despite the enormous expenses on waste management system in recent years - in 2007-2012 over 1.6 billion euro - in Poland low recycling level remains a biggest barrier. Over 80% of public funds were allocated for the construction, extension or modernization of municipal and medical waste management plants, including incinerators.

In the last strategy "National Waste Management Plan 2022", it is planned to reduce waste incineration. According to this plan the share of thermally transformed municipal waste and waste from municipal waste treatment in relation to municipal waste generated may not exceed 30% by 2020. But the province authorities are not willing to include new installations into waste management plans. In fact, older installations are favoured, in which outdated technologies often are functioning. Moreover, in the Polish legislation on waste, there are no regulations that can avoid the discretion of including the new installation into province waste management plans by marshal of the given province. From the Bioelektra's point of view, it can eliminate their company from the circular economy market.

Polish regulations are in favour of selective collection of at least 5 waste fractions. RotoSteril technology allows automatic waste segregation which is more effective than this achieved in traditional waste management systems based on selective collection and MBT technologies. Selective collection reduces economic benefits from utilizing MHT technologies. Combining MHT technology with selective collections system increases operating costs of the entire waste management system, as the costs of logistics and transport of segregated waste are very high. In Bioelektra' s opinion, municipalities should be able to choose a waste collection system depending on economic and environmental conditions. The Waste Directive at EU level formulates provisions that promote selective collection, but it keeps open the door to other systems, if they prove more benefits from a technical, environmental or economic point of view.

The additional restrictions for the circular business model development in the Polish law is - from Bioelektra perspective - the requirement to limit the place of waste treatment within the certain region. Particularly, stream of municipal solid waste must be processed at the place of origin, e.g. within the region. Thus, the collected municipal waste cannot be transported outside the region. All these factors imply that the competition within the sector is rather limited.


*Source: Bioelektra*



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# 4 Discussion & Conclusions

In this report the analysis of the Circular Economy Business Model of Bioelektra, focused mainly on the innovative technology and different barriers to implement it. One of the R2π project's aim is to identify and develop sustainable business models and guidelines that will facilitate the circular economy implementation in new entities and markets. Having those objectives in mind Bioelektra was chosen as one of the case organizations because of their ambition to change the way people think of waste. Their winning ambition is: „waste diverted from landfill". As a long-term effort it is fundamental for circular economy business models.

The main strength of Bioelektra business model, which is classified as a resource recovery CEBM following the R2PI framework, is meant by sourcing recycled or renewable materials that can be returned to either the technical or biological cycle.

Throughout the report, based on the use of different methods, enablers and barriers have been described. Among key enablers are: EU policies introducing restrictive requirements in waste management (landfilling reduction, high recycling levels), national and global need for efficient technology in municipal waste management, social needs to simplify separate collection systems, global policies for climate protection – reducing GHGs emissions, seeking for new sources of renewable energy, global need of carbon footprint reduction.

Key barriers are local legislation which can restrain innovative solutions and traditional attitude of local and national authorities, with "against any change" mindset. Waste management system is multidimensional and contains a multi-level governance system, embracing central governments for setting strategies, creating national plans, then regional and in most cases local authorities for designing and implementing policies and organising tools for waste collection, treatment, and disposal. For small companies like Bioelektra it can be the biggest barrier to survive and develop on the market in this legal environment.

Key enablers:

- EU policies introducing restrictive requirements in waste management
- need for efficient technology in municipal waste management
- social needs to simplify separate collection systems
- global policies for climate protection

Key barriers:

- local legislation is restraining innovative solutions
- traditional attitude of local and national authorities
- multidimensional waste management system

As shown in the report, Bioelektra has created a waste treatment technology that unveils resource potential in waste. It allows for simple methods of waste collection and does not require segregation-at-source. The technology respects local community by making waste odourless. It is also the most financially viable waste treatment technology – according to managers from the company, as municipal solid waste is sterilised and turned into resources. It creates new opportunities for local economies in different parts of the world by delivering streams of recycled resources to the market by achieving a diversion rate of over 96% from landfill.

The above implemented circular business model pattern seem replicable and transferable to other entities and offer substantial potential for positive environmental and economic benefits, not only in the waste management. Companies in different sectors can reflect on their specific context and product design based on resource recovery.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

Among key managerial considerations are:

- Make efficient use of resources in different phases of the life cycle
- Investigate the entire value chain for opportunities and resource efficiencies
- Collaborate across companies and sectors to find the best solutions for resource recovery
- Design for reusability and for the lowest negative impact on environment and human health
- Increase marketing of recovered resources to increase awareness of and demand for circular products

Key considerations for policy makers

- Introduction of restrictive requirements in waste management is necessary
- Simplifying waste collection system for citizens instead of complicating it
- Introduce on a wider scale a circular public procurement
- Ensure consistent regulations across EU
- Monitor implementation of circular package legislation in different EU countries



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# References

Aluchna, M., & Rok, B. (2018). Sustainable Business Models: The Case of the Collaborative Economy. In *Sustainable Business Models: Principles, Promise, and Practice* (pp. 41-62). Springer, Cham.

European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the loop – An EU action plan for the Circular Economy, COM2015 614 final.

European Commission, (2017). Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions - the role of waste-to-energy in the circular economy, COM/2017/0034 Final http://ec.europa.eu/environment/waste/waste-to-energy.pdf

Iacovidou, E., Millward-Hopkins, J., Busch, J., Purnell, P., Velis, C. A., Hahladakis, J. N., ... & Brown, A. (2017). A pathway to circular economy: Developing a conceptual framework for complex value assessment of resources recovered from waste. *Journal of Cleaner Production*, *168*, 1279-1288.

Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., & Hekkert, M. (2018). Barriers to the Circular Economy: Evidence from the European Union (EU). *Ecological Economics*, *150*, 264-272.

Lee, P., Sims, E., Bertham, O., Symington, H., Bell, N., Pfaltzgraff, L., ... & O'Brien, M. (2017). Towards a circular economy: waste management in the EU; study, European Parliamentary Research Service

Malinauskaite, J., Jouhara, H., Czajczyńska, D., Stanchev, P., Katsou, E., Rostkowski, P., ... & Anguilano, L. (2017). Municipal solid waste management and waste-to-energy in the context of a circular economy and energy recycling in Europe. *energy*, *141*, 2013-2044.

Montejo, C., Tonini, D., del Carmen Márquez, M., & Astrup, T. F. (2013). Mechanical–biological treatment: performance and potentials. An LCA of 8 MBT plants including waste characterization. Journal of Environmental Management, 128, 661-673.

Tisserant, A., Pauliuk, S., Merciai, S., Schmidt, J., Fry, J., Wood, R., & Tukker, A. (2017). Solid waste and the circular economy: A global analysis of waste treatment and waste footprints. *Journal of Industrial Ecology*, *21*(3), 628-640.

Wilts, H., and von Gries, N. (2014). Municipal Solid Waste Management Capacities in Europe. ETC/SCP working paper 8/2014

De Wit, M.; Hoogzaad, J.; Ramkumar, S.; Friedl, H.; Douma, A. The Circularity Gap Report: An Analysis of the Circular State of the Global Economy; Circle Economy: Amsterdam, The Netherlands, 2018.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# Appendix A: Bioelektra business context analysis tool

| | Company: _ | BIOELEKTRA | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRIVER | | | | | | Please, rank the following according to how much of a driver / barrier you think they represented for implementing your CEBM (put an X where appropriate) | BARRIER | | | | | |
| Not at all important | Slightly important | Moderately important | Very important | Extremely important | N/A | | Not at all important | Slightly important | Moderately important | Very important | Extremely important | N/A |
| | | | x | | | CE roadmap / initiative at the national / regional / local level | | | | x | | |
| | | | x | | | Setting of end-goals and monitoring (CO2, noise, movements) at the national / regional level | | | | x | | |
| | | x | | | | Activity permit (license) | | | x | | | |
| x | | | | | | Warranties law (e.g. second-hand products) | | | x | | | |
| | | x | | | | Intellectual property rights (e.g. components susceptibles of being reused) | | x | | | | |
| | | | x | | | International trade agreements (e.g. requirements in certain markets) | | x | | | | |
| | | | | x | | Dramatic change in a target market regulation (e.g. banning the use of plastic bags in China) | | | | x | | |
| | x | | | | | Competition regulation (e.g. positive discrimination for CE products is not permitted in public procurement) | | x | | | | |
| | | x | | | | Public subsidies that support linear economy (e.g. subsidies to fossil fuels, car purchase incentives) | | | | x | | |
| | | | | x | | Resource efficiency targets, requirements of reusing percentage of components and raw materials in new products | | | | x | | |
| | | | | x | | Waste regulation, recycling regulation, water regulation, energy regulation and choice restriction | | | | | x | |
| | | | | x | | End of life regulations | | | | | x | |
| | | | | x | | Mandatory take-backs | | | | | x | |
| | | | | x | | Extended Producer Responsibility | | | | | x | |
| | | | | x | | Material and design standards (national and across industries) | | | | | x | |
| | | x | | | | Controls and penalties (e.g. controls and sanctions on the use of specific products) | | | | x | | |
| | | | x | | | Fiscal measures (green taxes): land-value taxes, value-extracted tax, product levy and recovery rewards | | | x | | | |
| | | | x | | | Differentiated VAT rates (e.g. products with high recycled content included among VAT reduced goods) | | | x | | | |
| | | | x | | | Green public procurement (e.g. performance procurement by public sector) | | | x | | | |
| | | | x | | | Public subsidies for eco-innovation, eco-design | | | | x | | |
| | | | x | | | Public support for demonstration and commercialisation of innovation in Circular Economy (technology platforms, pre-commercial procurement, lead markets) | | | x | | | |
| | | x | | | | Availability or prices of raw materials that support linear economy (water and energy included) | | | | | x | |
| | | | x | | | Availability or prices of raw materials and products that support CE | | | | | x | |
| | | | x | | | General economic "health" of incumbent companies in a sector (crisis, decline, stability, growth) | | | | x | | |
| | x | | | | | Competition trends in the market | | | x | | | |
| | | | | x | | CE-supportive business environment (technology providers, advanced services, eco-design businesses...) | | | | x | | |
| | | | | x | | Relevant and expanding CE / environmentally oriented market segment in the country / region | | | | x | | |
| | | | x | | | Market purchase capacity | | | x | | | |
| | | | | x | | Suitable infrastructure for recycling and recovery / other (e.g. supporting shared use) | | | | | x | |
| | | | x | | | IT-infrastructure (supporting transparency and information sharing; joint collection systems; match-maker mechanisms) | | | | | x | |
| | | x | | | | Extensive raw materials information service | | | | | x | |
| | | x | | | | Funding opportunities / venture capital for CE-related investment | | | | x | | |
| | | | x | | | (Green) lending programmes from banks | | | | x | | |
| | | | x | | | Apropriated technologies for CE | | | | x | | |
| | | x | | | | Major technological trends in the sector; new sectoral developments | | x | | | | |
| | | | x | | | R&D capacities and strengths (innovation agency, university research groups supportive to CE) | | x | | | | |
| | | x | | | | R&D capacities and strenghts in green energy | | | x | | | |
| | | | | x | | Public support for CE-related R&D (new materials, new products/services, supply chain resource tracking) | | | x | | | |
| | | | x | | | Training in CE-oriented activities | | | x | | | |
| | | | | x | | Rural vs urban distribution of population | | | | x | | |
| | x | | | | | Ratio of young vs old population | | | x | | | |
| | | | | x | | Social attitudes towards waste and recycling in the country | | | | | x | |
| | | | x | | | Social attitudes towards eco-friendly production and consumption in the country | | | | | x | |
| | | | x | | | Social attitudes towards water use in the country | | | | x | | |
| | | | x | | | Social attitudes towards energy use in the country | | | | x | | |
| | | x | | | | Social movements pressure regarding environmental problems (NGOs, civil society) | | | | x | | |
| | | x | | | | Preference for green brands / products, services by consumers in the country | | | x | | | |
| | | | | | | Perception of environmental problems by businesses in the sector / country | | | | | x | |



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# Appendix B: Bioelektra business model circularity

| | Tending towards LINEAR model | N/A | 1 | 2 | 3 | 4 | 5 | Tending towards CIRCULAR model |
|---|---|---|---|---|---|---|---|---|
| PRODUCT | We have not characterised the identity of our products in terms of generic materials (e.g., aluminum, polyethylene, steel etc.) | | | | | | x | The product is 100% characterized by its generic materials (e.g., aluminum, polyethylene, steel etc.) and/or product categories and names (e.g., coatings, paints, detergents, seating furniture). |
| | We have not assessed the chemical composition of materials (recycled materials included) used within our product. | | | | | | x | We have fully assessed the chemical composition of all materials (recycled materials included) used within our product. |
| | We do not seek to use recycled materials in our product | | | | | | x | We maximise the use of recycled materials from pre- or post consumer waste in our product and source these from outside of the manufacturer's facility. |
| | We do not seek to use third party co-product or waste streams as an input to our own production | | | | | | x | We maximise the use of third party co-product or waste streams as an input to our own production |
| | We do not seek to use remanufactured, refurbished, or repaired parts and components within our products | | | | | | x | We maximise the use of remanufactured, refurbished, or repaired parts and components within our products |
| | We do not not seek to use rapidly renewable materials in our product | | | | | x | | We maximise use of rapidly renewable* materials in our product |
| | We do not not seek to use compostable/biodegradable materials in our product | | | x | | | | We maximise use of materials in our product that are commonly known to biodegrade or are able to undergo biological decomposition |
| | We do not consider the 'recyclability' of materials used in our products | | | | | x | | We only use materials in our products that are proven to be technically and economically recyclable (e.g. non-toxic, separatable into material streams, etc.) |
| | Planned obsolescence is built into product design | | | | | x | | Product is designed for durability |
| | Product technical lifetime is below industry average | | | | | x | | Product technical lifetime is above industry average |
| | Product functional lifetime is below industry average | | | | | x | | Product functional lifetime is above industry average |
| | Product warranty period is below industry average | | | x | | | | Product warranty period is above industry average |
| | Product is not designed for disassembly to enable component/material recovery or reuse; nor is it biodegradable | | | x | | | | Product is designed to be economically disassembled enabling component/material recovery or reuse; OR is biodegradable with no further intervention needed to reclaim the nutrients |
| | Product is not designed with the intention to return to a 'technical' or 'biological' cycle, nor is there a defined plan for product recovery and reutilization. | | | x | | | | Product designed to return to a 'technical' or 'biological' cycle, and a plan for product recovery and reutilization is defined. |
| | Product is not designed to be repairable | | x | | | | | Product designed to be economically repairable (by user or third party) |
| | Product not designed to be upgradable | | x | | | | | Product designed to be upgradeable, adapting to changing customer needs (e.g. by being modular, via software upgrades, etc.) |
| | Re-manufacturing is not taken into account in product design | | | | x | | | Product is designed to be economically re-manufactured |
| BUSINESS MODEL | Revenue driven mainly by asset sale | | | x | | | | Revenue driven mainly by monetising usage and/or performance of asset |
| | Value exchange mainly focused on driving a product sale transaction (e.g. competitive price) | | | x | | | | Value exchange focuses on customer lifetime benefit (including reducing/controlling cost of ownership; asset performance) |
| | Value proposition focuses on the product | | | | x | | | Value proposition is positioned as a service (including product/service bundle) |
| | Value proposition does not include maintenance or other value-added services | | | x | | | | Value proposition includes bundled maintenance or other value-added services |
| | We do not seek to reuse and put back into our production the co-products or waste streams from our operations. | | | | | x | | We maximise the reuse of co-products or waste streams from our operations, putting them back into our production. |
| SYSTEM | Repair services and availability of spare parts are not actively established | x | | | | | | Repair service network and spare parts are actively established in the market |
| | Re-manufacturing services not actively established in market | | | | | x | | Re-manufacturing services actively established in market (own, or third party) |
| | We do not seek to reuse co-products or waste streams from our operations as an input to third party production (e.g. through direct or indirect supply relationships) | | | | | x | | We maximise the reuse of co-products or waste streams from our operations by supplying them to third parties as an input into their production (e.g. through direct or indirect supply relationships) |
| | We do not have in place a take-back or recovery scheme for our products at end-of-life (own or via a third party) | x | | | | | | We have in place a take-back or recovery scheme that fully covers all our products at end-of-life (own or via a third party, e.g. EPR arrangement) |
| | We do not have in place a take-back or recovery scheme for components our products at end-of-life (own or via a third party) | x | | | | | | We have in place a take-back or recovery scheme that fully covers all components from our products at end-of-life (own or via a third party) |
| | We do not have in place a recycling arrangement for materials within our products at end-of-life (own or via a third party) | | | | | x | | A recycling infrastructure is widely available for this type of product, and the material is already commonly recycled in practice with no special disassembly required |
| | We do not provide incentives to return our product at end-of-life | | | | x | | | We provides incentives to return our product at end-of-life (e.g. deposit, exchange, cash) |
| | We have no visibility on the actual effectiveness of our product take-back at end-of-life | | | | x | | | We have full visibility on the actual effectiveness of our product take-back at end-of-life |
| | We have no visibility on the destination of our products taken back at end-of-life | | | | x | | | We have full visibility on the destination of our products taken back at end-of-life |
| | We have no visibility on the actual effectiveness of material recycling from our products recovered at end-of-life | | | | | | x | We have full visibility on the actual effectiveness of material recycling from our products recovered at end-of-life |
| | We have no visibility on the destination of materials recycled from our products at end-of-life | | | | | | x | We have full visibility on the destination of materials recycled from our products at end-of-life |



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378

# Appendix C: Bioelektra business model strengths & weaknesses

| | | Weaknesses | N/A | 1 | 2 | 3 | 4 | 5 | Strengths |
|---|---|---|---|---|---|---|---|---|---|
| Value Proposition | | | | | | | | | |
| | 1 | Our value proposition leaves significant customer segments' needs unmet | | | | | x | | Our value proposition fulfils all significant needs of target customer segments |
| | 2 | Customer satisfaction is low | | | | | | x | Customer satisfaction is high |
| | 3 | Our value proposition has no network effects | | | | | x | | Our value proposition has strong network effects |
| | 4 | Our charging and pricing models don't meet customer needs and expectations | | | | | | x | Our charging and pricing models effectively meet customer needs and expectations |
| | 5 | *We do not capture 'sustainability value' created for customers* | | | | | | x | *We fully capture 'sustainability value' created for customers* |
| Cost/Revenue | | | | | | | | | |
| Margins | 6 | Our margins are low compared with competitors | | | | x | | | Our margins are high compared with competitors |
| Revenues | 7 | Our revenues are unpredictable | | | | | x | | Our revenues are predictable |
| | 8 | Each sale requires additional effort | | | x | | | | Each sale generates follow-on recurring revenue / repeat purchases |
| | 9 | We earn no revenue before incurring costs of goods/services sold | | | x | | | | We earn revenue before incurring costs of goods/services sold |
| Costs | 10 | Our costs are unpredictable | | | | | x | | Our costs are predictable |
| | 11 | Our product cost structure is substantially higher than that of competitors | | | | | | x | Our product cost structure is substantially lower than that of competitors |
| | 12 | Our service cost structure is substantially higher than that of competitors | | | | | | x | Our service cost structure is substantially lower than that of competitors |
| | 13 | Our cost structure has low economies of scale | | | | | x | | Our cost structure has high economies of scale |
| | 14 | Our cost structure is asset-heavy and costs are mainly fixed | | | x | | | | Our cost structure is asset light and costs are mainly variable |
| | 15 | Our cost to serve customers is misaligned with customer segments | | | | | x | | Our cost to serve customers is aligned with customer segments |
| Operating Model | | | | | | | | | |
| Key Activities | 16 | Our key activities can be easily copied by competitors | | | | | x | | Our key activities are hard to copy by competitors |
| | 17 | Our key activities need significant investment in order to scale with growth | | | x | | | | Our key activities easily scale with growth without needing significant investment |
| | 18 | Our key activities do not fulfil the core competencies we need | | | | | x | | Our key activities match the core competencies we need |
| | 19 | *Our key activities poorly support circular economy within our business model* | | | | | | x | *Our key activities fully support circular economy within our business model* |
| Key Resources | 20 | Our key resources do not meet the needs of our business model | | | | | x | | Our key resources fully support the needs of our business model |
| | 21 | *Our key resources poorly support circular economy in our business model* | | | | | | x | *Our key resources fully support circular economy in our business model* |
| | 22 | Our key resources can be easily built or acquired by competitors | | | | | x | | Our key resources are very hard to build or acquire by competitors |
| Key Partners | 23 | Key partners do not provide us with competitive advantage | | | | x | | | Key partners provide us with exclusive competitive advantage |
| | 24 | *Key partners poorly support circular economy within our business model* | | | | | x | | *Key partners enable circular economy within our business model* |
| | 25 | Key partners do not contribute any value to us for free | | | x | | | | Key partners contribute value to us for free |
| | 26 | Customers do not contribute any value to us | | | | x | | | Customers contribute value to us (for free) |
| Customer Interface | | | | | | | | | |
| Customer Segments | 27 | We do not understand the full potential value that could be created for customers | | | | | | x | We understand the full potential value that could be created for customers |
| | 28 | Customer loyalty is low | | | x | | | | Customer loyalty is high |
| | 29 | Customer churn is high (customer retention is low) | | | | | x | | Customer churn is low (customer retention is high) |
| | 30 | New customer acquisition rate is low | | | | | x | | New customer acquisition rate is high |
| | 31 | Our market share is shrinking | | | | | | x | Our market share is growing |
| Customer Channels | 32 | Our customer channels do not effectively communicate our value proposition | | | | | | x | Our customer channels effectively communicate our value proposition |
| | 33 | Our customer channels do not effectively deliver our value proposition | | | | | x | | Our customer channels effectively deliver our value proposition |
| | 34 | Our customer channels are misaligned to target customer segments | | | | | x | | Our customer channels are well aligned to target customer segments |
| Customer Relationships | 35 | Our customer channels do not effectively reach target customer segments | | | | x | | | Our customer channels effectively reach target customer segments |
| | 36 | Our customer relationships are weak | | | | | x | | Our customer relationships are strong |
| | 37 | Our customer relationship model(s) are misaligned with customer expectations | | | | | x | | Our customer relationship model(s) are aligned with customer expectations |
| | 38 | Our customer relationship model(s) are misaligned with our value proposition | | | | | x | | Our customer relationship model(s) enhance our value proposition |
| | 39 | Our customers can switch to a competitor at any time | | | x | | | | Our customers are locked into long-term relationships |



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 730378