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Implementation of a circular economy-based business model for landfill management companies

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Demand for raw materials by the world economy could increase by a further 50% in the next 15 years. In order to reverse the trend, a circular development model has to be adopted, which would keep materials and their value in circulation. This is the only solution able to maintain sustainability alongside economic growth.
The Latvian waste management system currently relies heavily on landfilling, with a landfilling rate of over 70% in 2014. In a period when waste policies guarantee the supply of secondary raw materials and prevent valuable materials from getting lost in landfills or incineration, it is of vital importance to start shifting to a circular economy-based business model, particularly for landfill management companies.
The **purpose** of the research paper is to develop a business model for a landfill management company that will facilitate efficient management of resources and their sustention within the economic cycle. The authors have developed the research based on mathematical modelling of resource flows for maximum economic benefit from their management. The model is dynamic as it depends on a wide range of parameters and the economy – changes in independent variables directly affect the model output.
The methods used in the paper will be economic assessment with material flow analysis as well as systems dynamics for decision-making. The research is limited to analysis of municipal waste.
One of the main findings and practical implications will be a tool for decision-making based on the authors' industrial symbiosis model. Industrial symbiosis fits perfectly into the circular economy concept and is an option for Latvian landfill management companies in promoting resource efficiency, especially taking into account that Latvia is underperforming in the management of primary resources.
The **originality** of the paper is underscored by the lack of similar studies in Latvia. The research will be of a **value** for specialists in the municipalities, responsible for waste management, and for waste management companies, allowing them to improve their business model as well as to foresee and decrease operational risks and optimize transportation costs. The paper is **designed** as a research paper.

Keywords: circular economy, decision-making, industrial symbiosis, landfill management companies.

INTRODUCTION

According to a report by the Committee on the Environment, Agriculture and Local and Regional Affairs (2007), proper management of solid waste is a central pillar of far-sighted, sustainable environmental policies. Every citizen of the EU generates approximately 1 kg of solid household waste a day and the figures show an upward trend. Management of household waste is therefore one of the major challenges currently facing local authorities.

Over the twentieth century, the world increased its fossil fuel use by a factor of 12, whilst extraction of material resources increased by a factor of 34. Today in the EU, each person consumes 16 tons of materials annually, of which 6 tons are wasted, with half going to landfills for disposal (EU COM, 2011; DG ENV, 2012). The World Business Council for Sustainable Development estimates that by 2050 a 4 to 10-fold increase in resource efficiency will be required, with important improvements already achieved by 2020. This also means that significant measures in the field of waste management are to be taken instantly. The Europe 2020 Strategy and its flagship initiative "A Resource-Efficient Europe" set the EU on the path to this transformation. Across the EU 28 average domestic material consumption in 2014 reached 13.296 tons per capita; in comparison Latvia's domestic material consumption was 21.504 tons per capita. Domestic material consumption is defined as the total amount of material directly used in an economy and equals direct material input minus exports. Taking into account the fact that currently the circular economy, resource efficiency and the concept of resource sharing (industrial symbiosis) are becoming more important and the fact that Latvia is very inefficient in resource exploitation per capita, waste management is viewed as a potential field that could be assessed first in order to improve the ratio (Eurostat Press Office, 2015; Eurostat, 2017).

During the time period when waste management infrastructure was in the development stage in Latvia, the EU was quite active, working on legislative improvements. For instance, in the mid-2000s it performed a feasibility check of Directive 2008/98/EC on waste (Waste Framework Directive) and developed amendments to the Directive. The amendments entailed a significant shift in policy, changing the waste management hierarchy's accents (stressing a focus on recycling, reuse and recovery) and developing a range of landfilling bans. This stage had a significant impact on landfill functioning. Thus, unconsciously, waste landfill sustainable development was endangered on the EU level, especially for the member states, where a significant volume of waste is still being landfilled. When applying these legislative changes in Latvian landfill management companies (hereinafter – LMCs), it should be noted that waste landfills are complicated elements of the infrastructure which cannot adapt instantly to such changes.

In the Latvian case, this means that in the nearest future a decision on significant changes in the current waste landfill sustainable development strategy are required. In the nearest future no implementation of any revolutionary waste treatment technologies is foreseen and a decrease of disposed waste from 71% in

2014 to 10% or even 5% in 2030 poses a threat for the existence of waste landfills and their economic stability.

According to EU COM (2015), it is important to promote innovative industrial processes, for example, industrial symbiosis, which allows waste or by-products of one industry to become inputs for another. The concept of the circular economy and industrial symbiosis as one of its sub-systems sounds like a good option in order to solve the current problems of Latvian inter-municipal landfill management companies.

Analysis of the current situation within Latvian LMCs has revealed a negative trend in which some companies have problems combining managerial, entrepreneurial and environmental decisions – companies dealing only with landfilling are interested in an increase in landfilled waste volumes, but this is in direct conflict with the latest EU trends in the landfilling of waste, in which member states are to focus on decreasing landfilled waste as much as possible. Currently it is of vital importance to develop a smart and sustainable decision-making system that will allow LMCs not only to fulfil their financial obligations but, as entities, to generate a positive cash flow and choose further development options. Currently the EU provides aid for recovery and recycling activities; these activities alongside an inhabitant education programme will also have an impact on waste prevention and final waste volume reaching a landfill. All this leads to the conclusion that, in order for an LMC to become economically effective, a new management approach has to be considered. The outcome of the research is applicable not only to Latvian waste management companies, but also to all EU and non-EU countries, which still rely significantly on landfilling.

MATERIALS AND METHODS

The object of the research is Latvian landfill management companies. The data for the empirical part of the research has been collected by means of a survey. The survey was developed in order to prove the authors' vision of possible LMC development, with two main focus groups – a landfill group (covering LMCs) and an expert group (including experts in the field of waste management from Latvia, Estonia, Lithuania, Russia, Malaysia and Spain). The respondents in the landfill group were mainly top managers or members of the board of LMCs, while the expert group comprised representatives of foreign LMCs, consultants, experts from ministries of environmental protection and academics. The questionnaire was completed by 10 LMCs, which accounted for 91% of Latvian LMCs, and 20 experts, which accounted for 67% of the primary target group. The research is based on qualitative methods (survey and situation analysis) and quantitative methods, such as Latvian waste management system data analysis (primary and secondary data) benchmarking, systems dynamics (logical causal-loop diagrams), mathematical modelling and data evaluation.

For the empirical study, *Excel (MonteCarlo modelling)* and *Vensim* software was used. The data was obtained from the survey, mathematical modelling and statistical databases offered by Eurostat, the World Bank, the Confederation of European Waste-to-Energy Plants and the OECD.

RESULTS AND DISCUSSION

The rapid growth in the world population over the last 50 years has caused an immense increase in the demand for food. It has been estimated that the world population will reach 9 billion by 2050, requiring a 60%–70% increase in food production (Moraes et al., 2014). However, the Food and Agriculture Organization of the United Nations (FAO) estimates that more than 1.3bt of food are wasted every year (Bräutigam et al., 2014). This means that significant quantities of resources employed for food production are used in vain and have a significant environmental impact, such as an increase in the quantity of greenhouse gases generated (FAO, 2011). Therefore, the European Commission has promoted the reutilization of waste by means of the circular economy (Laso et al., 2016).

Back in 1990, Pearce and Turner introduced the concept of a circular economy into mainstream economic theory. In their well-known textbook on environmental economics, the authors addressed the interlinkage between the environment and the production/consumption economic model. In their newly proposed circular scheme, the environment provides amenity values and is a resource base, a foundation for economic activities, and a fundamental life-support system (Pearce, Turner, 1990).

The circular economy appears in the literature through three major activities, the so-called 3R's Principles: Reduction, Reuse and Recycle (Feng and Yan, 2007; Ren, 2007; Preston 2012). It should be noted that circular economy concepts have already been adopted on national levels. For example, in China, where environmental protection is a very important issue, in 2009 the Circular Economy Law was passed and entered into force. Austria, Germany, and the Netherlands have to some extent already developed strategies compatible with circular economic activities (Cudecka-Purina, Atstaja 2017; Heck, 2006; Goorhuis et al. 2012). As highlighted by Morone, Navia (2016), the purpose of consumption is to increase the consumer's utility and/or enhance social welfare. However, at each stage of the supply chain, waste is produced. To some extent this waste might be recycled and reconverted into resources, reducing the need to mine virgin resources and, through this, the economy becomes circular. Yet, not all waste can be recycled or is recyclable, partly owing to missed opportunities and partly owing to basic physical and thermodynamic laws. The amount of waste that can be recycled depends crucially on the capacity of the environment to assimilate residuals from the economic system. Once the assimilative capacity is exceeded, environmental damage occurs. To reduce the economy's impact on the environment, awareness of environmental issues is required on the part of society and entrepreneurs (Cudecka-Purina, Atstaja, 2012). Researchers have emphasized the necessity of significant reduction of the environmental impact of economic activities to avoid the collapse of civilization, and change should come from society by transforming dominant cultural patterns, changing attitudes and behaviour (Assadourian, 2010; Jackson, 2009).

DECISION-MAKING PROCESS

Waste management is a field that relies a lot on sustainable and long-term decision-making processes. Thus, it has certain boundaries. It should be considered that waste management in European Union member states has the following main stakeholders: the European Union, countries, regional municipalities, landfill management companies, NGOs and society. Limitations exist ranging from type of activity to waste sources analysed. Hung et al. (2007) note that the factors considered in municipal waste management models are mainly economic (e.g., system cost and system benefit), environmental (air emission, water pollution) and technological (the maturity of the technology). Three models have played a major role in the decision-making of municipal waste management: life cycle assessment, multi-objective programming and multi-criteria decision-making (Alidi, 1996; Powell, 2000).

The most popular and viable waste management models developed to support decision-making and selection of an optimal waste management strategy can be classified as:

- Models based on the *cost-benefit analysis* of the waste management system studied;
- Models that consider environmental, energetic and material aspects of the waste management strategy – *life cycle assessment*;
- *Multi-criteria decision-making* models for selection of the optimal waste management strategy (Morrissey and Browne, 2004).

Life cycle assessment focuses on environmental aspects, whereas maximization of economic efficiency is the major goal of cost-benefit analysis. Multi-criteria decision-making, however, allows for consideration of the three pillars of sustainability: economic, social, and environmental criteria (Karmperis et al. (2013), Milutinović et al. (2014)). In fact, multi-criteria decision-making can guide decision-makers in evaluating existing or potential alternatives by simultaneously applying multiple conflicting criteria (Kou et al., 2011; Zhou et al., 2010).

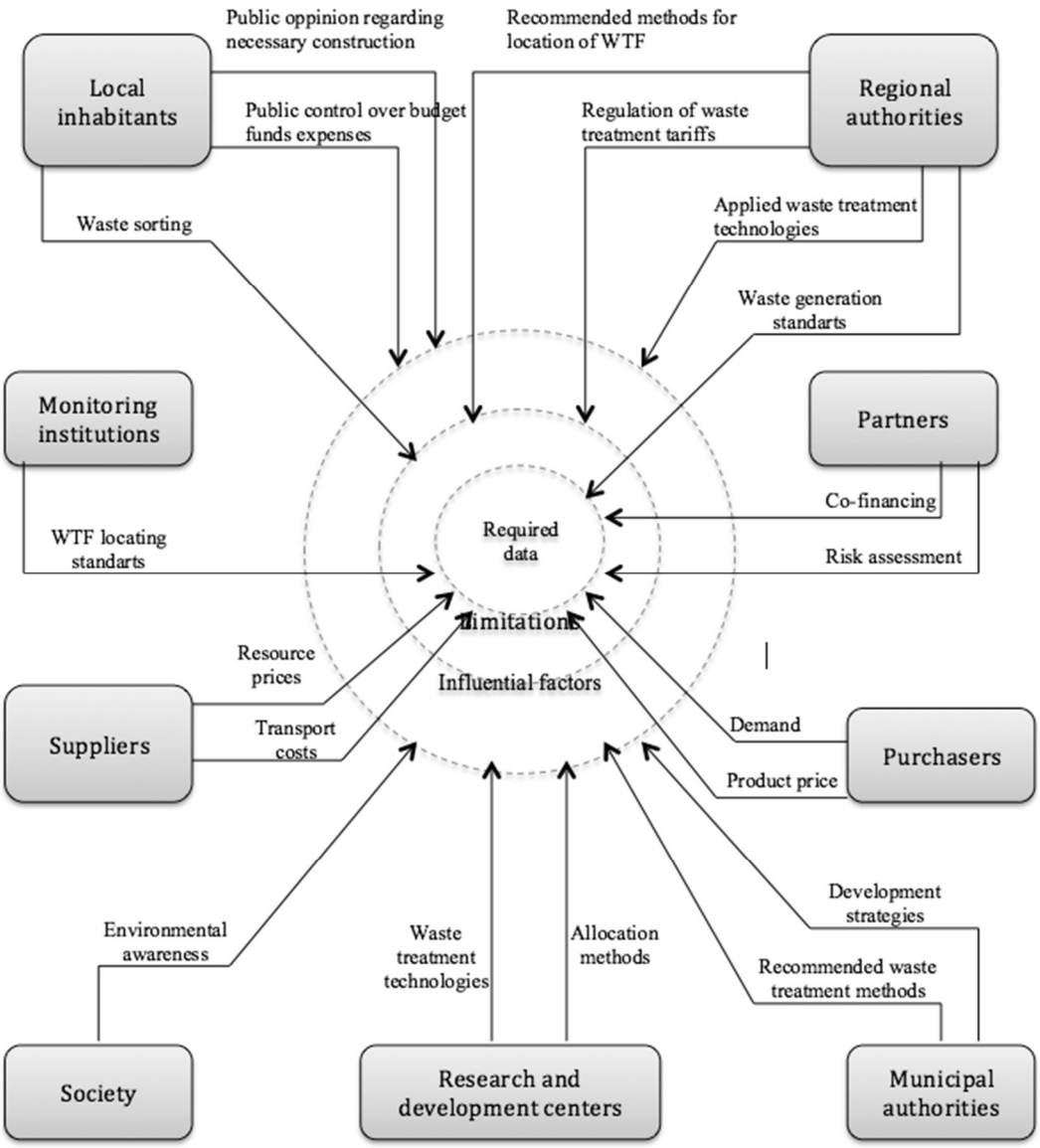
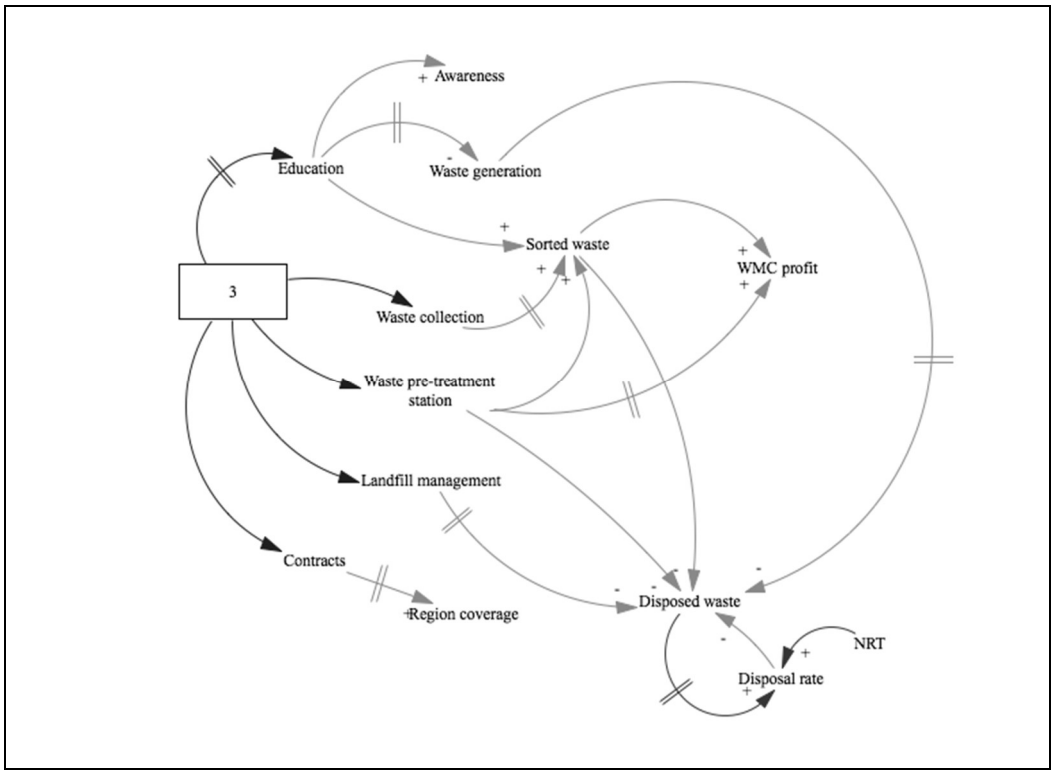


Figure. 1. Information flow for the decision-making process for locating a waste management infrastructure element
(Source: adapted from Velikanova, 2014)

Because of their ability to handle several criteria, multi-criteria decision-making methods are considered to be some of the most effective and thorough decision support frameworks for decision-making in solid waste management (Soltani et al., 2015).

RESULTS OF THE SURVEY

The authors created a survey with specially developed questions in order to confirm or dispel their theory that industrial symbiosis is the direction landfill management companies should follow in order to improve their sustainability and increase efficiency. The survey consists of 19 open and closed-type questions and is divided into three sub-sections. The first sub-section covers landfill management companies, their functions, the output of a landfill's daily operation activities, potential resources for industrial symbiosis and disposal rates. The following sub-section covers waste management tendencies in Latvia; it aims to disclose a landfill management company's vision on further development. And the last sub-section tackles decision-making practices in waste management companies. The authors have analysed the sample set and, in order to make it more representative, developed two types of surveys. The target audience or affected party of the research within Latvia is municipal landfill management companies. In addition, the authors have modified the same survey for experts in the waste management field (experts not directly engaged with the issues of landfill management company sustainability) who comprise both Latvian and foreign experts (from Estonia, Lithuania, Russia, Spain, and Malaysia). This group will hereinafter be called the "expert group".



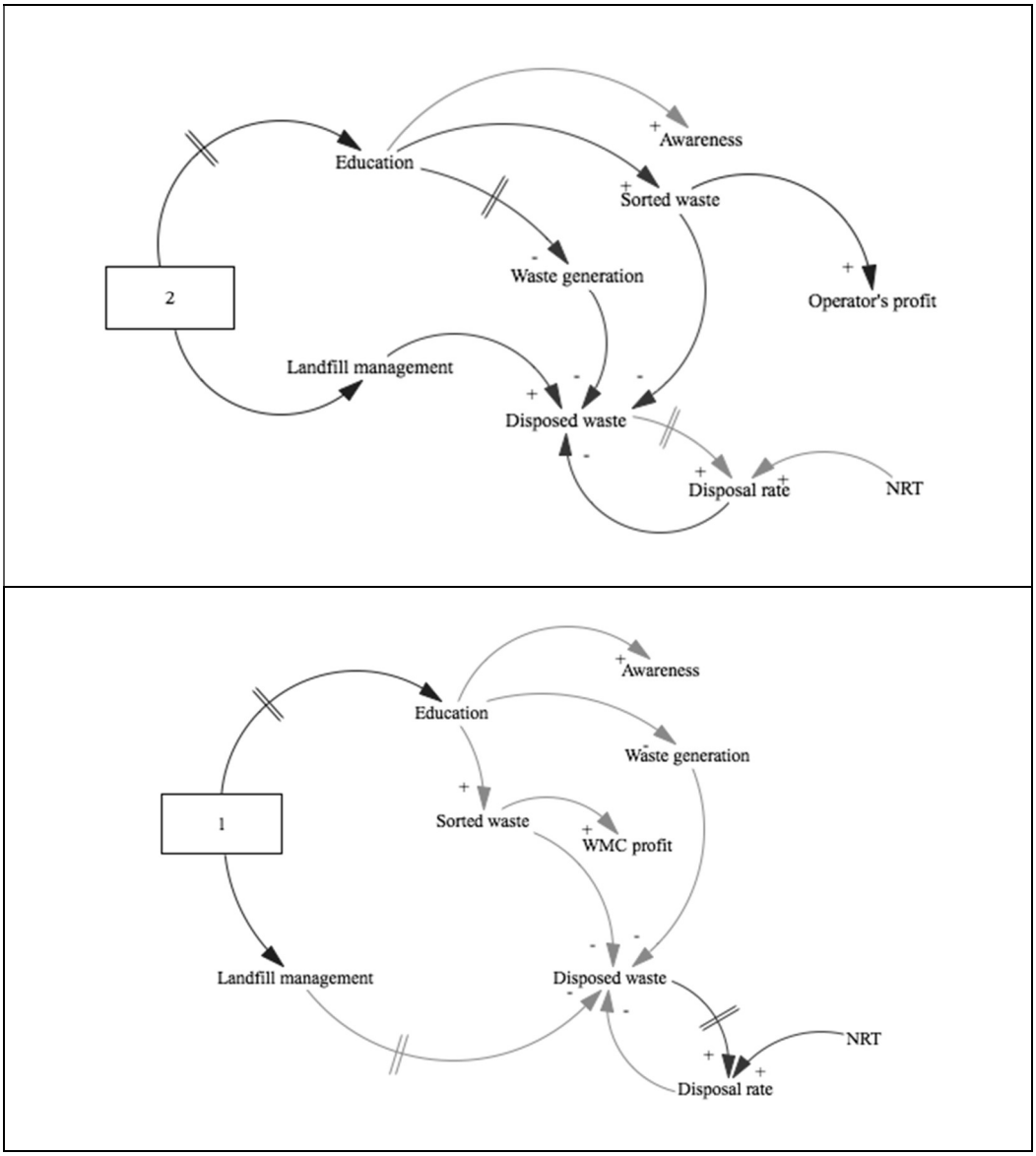


Figure 2. Causal loop diagrams of LMCs

Where:

1 – represents LMCs doing landfilling, sorted waste collection and education activities

2 – represents LMCs doing only landfilling and education activities

3 – represents full-cycle LMCs

(Notes for Fig. 2.: interrupted arrows have an effect in the long-term, + have a positive effect from LMCs' point of view, - have a negative effect; blue arrows are neutral, green are positive, red are negative)

The Latvian waste management system was not designed using a "one size fits all" approach; rather, it allowed municipalities to choose the management and operation a landfill management company should undertake. All 11 household waste landfills are

municipality-owned – each region has an intermunicipal waste management company (LMC) operating a landfill. Regarding other waste management activities, here the regions start to vary. Based on the results of the survey, the authors have analysed all the operations undertaken by LMCs and developed the schemes above.

Table 1.

SWOT analysis of a landfill management company

Strengths	Weaknesses
Regional monopoly	Lack of own financing
On-site waste treatment	Dependence on waste flow
Strong market entry barriers	Waste disposal tariff is approved by the
Fully public companies	Public Utilities Commission
Vertical integration in the in-house case[2]	Research capabilities
	All the incomes must deduct the waste disposal tariff
Opportunities	**Threats**
Development of waste treatment facilities	EU targets on waste landfilling limitations
Development of industrial symbiosis on a landfill basis	EU targets on landfill ban of certain materials
Resource availability for sharing	Changing policies
Cooperation with other industries	Global waste trends
	Energy prices

The SWOT analysis provides us with a full picture of internal variables which influence daily operation and long-term development of landfill management companies. In order to ensure their feasibility, LMCs have to elaborate a long-term development strategy, taking into consideration all the factors stated above.

Some of the results of the survey are provided below. Question No. 3 "What are the resources that arise during daily operation of a landfill?" provided us with a picture of the resources that are produced during a landfill's daily operations. Figure 3 shows that landfills do rely on sorting, gaining sorted waste from it (such as paper and cardboard, plastics, metals) as well as other reusable materials with market value. Purified leachate is obtained by all landfills – thus it should be mentioned that this product has negligible value, being used internally as technical water or for fire-extinguishing pools. The expert group sees, as the main by-products, all of the options (70%-90%), except for RDF (60%), compost used for road construction (40%) and compost for agricultural purposes (25%). This is due to the fact that production of RDF in many countries is done before waste reaches the landfill. Regarding compost production – unless a separate collection of biodegradable waste is ensured, no high-quality compost production is possible. This is due to the fact that the compost would be full of residual waste and heavy metals, which would be a problem for meeting agricultural fertilizer quality.

[2] In the future, all landfill management companies may become vertically integrated. The more functions a municipality assigns to an entity, working on the in-house principle, the lower the possibility for private companies to enter the market.

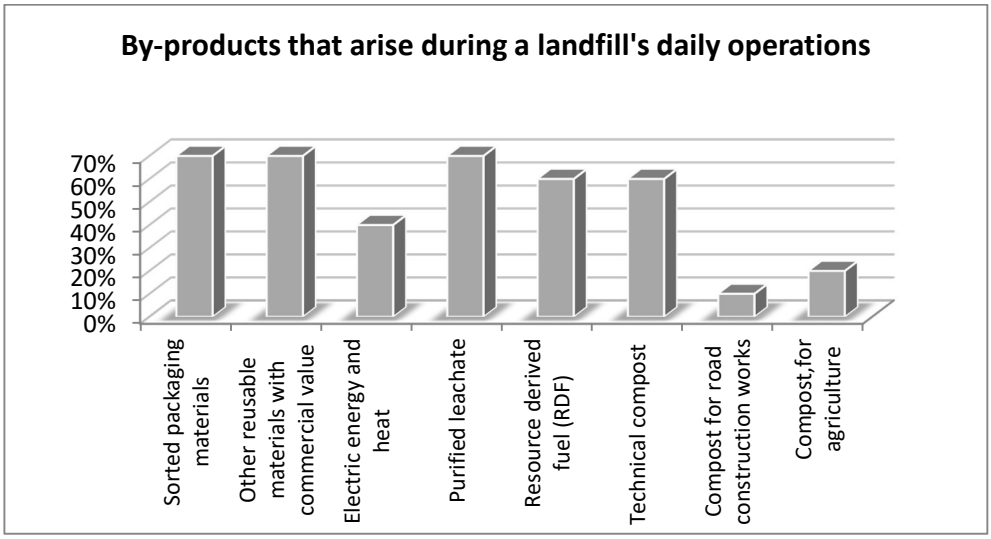


Figure 3. Resources that arise during a landfill's daily operations – response of the landfill group

In addressing the question **"What are the resources that could be offered for other companies?"**, i.e. that are either not used in an efficient manner or not used at all, the expert group identified the resources indicated in Figure 4, mostly focusing on education of society and awareness creation. They also pointed out that landfills should be as open as possible to teaching people to sort waste. The next step is to promote waste reduction and prevention. This means promotion of repair and reuse, especially for electric, electronic and bulky waste. According to the responses of the landfills, they see themselves as fully involved in sharing experience, education of society (80%), and organization of excursions and trainings (90%), followed by technical equipment (60%), infrastructure required for business establishment (fenced territory, supply road, premises, etc.) (50%) and exchange of energy commodities (30%).

This leads to a very important question analysed within the questionnaire: **"What could be a stimulating factor for a landfill management company to get involved in industrial symbiosis?"** Landfill management companies point out as the most stimulating factor (44% of respondents) education of society, explaining that the modern landfill is environmentally safe and different types of manufacturing can be allocated within its territory.

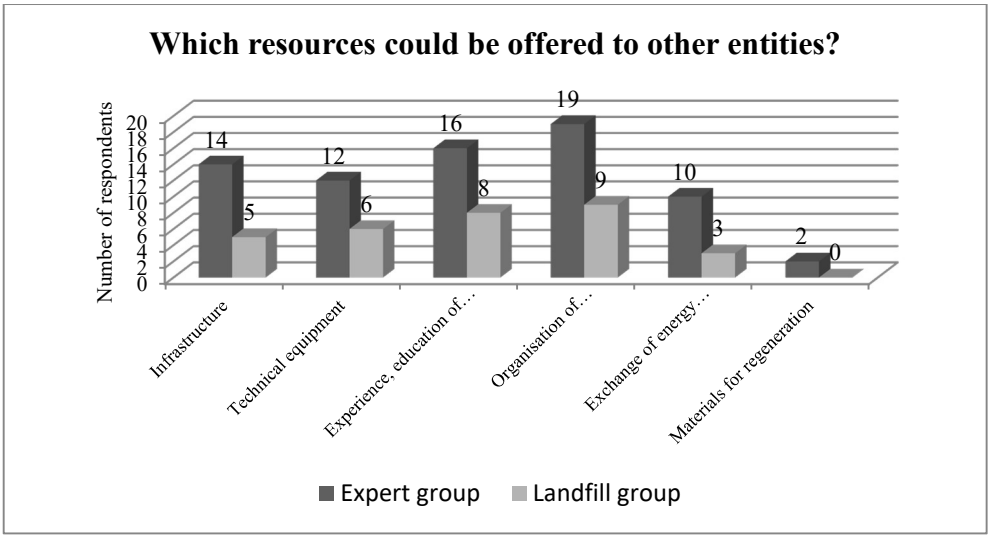


Figure 4. Resources that could be offered to other entities

This is followed by the necessity of developing state support programmes in order to facilitate cooperation of different sectors – identified by 39% of respondents. 6% see the main obstacle in legislation, pointing out that it has to be redeveloped in order to promote interdisciplinary cooperation. On the other hand, 11% of respondents consider that the existing legislation is sufficient and companies themselves are already starting to develop industrial symbiosis on a landfill basis. When it comes to the expert group, regarding the same question, 75% of respondents support the idea of state aid necessity, followed by reconsideration and revision of the legislative basis (45%); only 15% of respondents consider the legislative basis to be sufficient and 25% of the expert group stress the necessity of educating society.

DEVELOPMENT OF A DECISION-MAKING MATRIX

A range of problems that are currently faced by landfill management companies and do not allow them to engage directly in industrial symbiosis has been identified. This means that the first obligatory stage in promoting involvement in industrial symbiosis is the necessity to revise and change or amend legislative acts in order to stimulate promotion of such activities.

One of the obstacles identified is the Commission's Decree No. 1/5 of February 16, 2017 "Household waste disposal tariff calculation methodology" (Public Utilities Commission, 2017), as currently it does not directly support any additional activities that could be undertaken by landfill management companies. In addition, it should be mentioned that with the present regulations, in case a landfill starts successful implementation of industrial symbiosis which would generate additional profit, it would have to decrease the landfill rate, which, in turn, would decrease inhabitants' costs. But at this point, it should be stressed that this action would not be environmentally fair, as inhabitants would receive a discount in

payment without any increase in participation in waste management activities (sorting, reuse, etc.). Figure 5 provides a current picture of by-products generated from Latvian landfills' daily operations. This figure could be modified in the future, as landfills are evolving and new waste treatment options are appearing. The resources available within a landfill fall into 4 categories: a) materials, b) energy, c) services, d) skills. Research undertaken revealed that industrial symbiosis can be implemented in wood processing (for example – technical water, heat), agriculture (heat for greenhouses), greening, road construction (technical compost), domestic heating, construction materials, fish and pig farms (technical water, heat), etc.

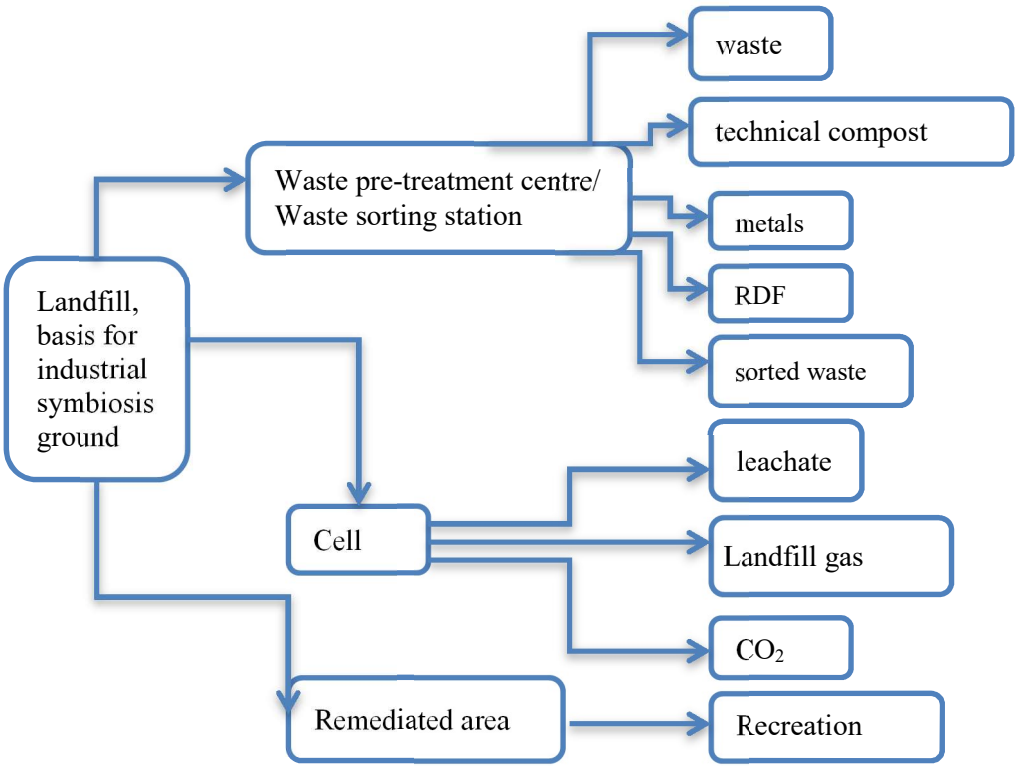


Figure 5. The landfill as a basis for industrial symbiosis

Within this research a model has been developed, presented in Figure 6, where:

- x_1, x_2, $x_{...}$, x_n – are the input data, i.e. waste flows that reach the waste landfill site (which includes the sorting station and waste pre-treatment centre),
- y_1, $y_{...}$, y_m – are the output resources that are left so far without appropriate application within a landfill site,
- z_1, z_2, z_k – industries which may take advantage of y resources and save the consumption of primary resources.

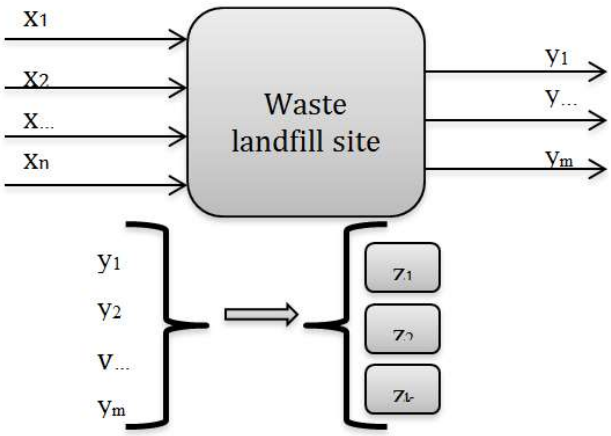


Figure 6. Energy flows within a landfill

The development paths of LMCs, according to the authors' concerns, should include primary resource consumption and assessment of critical resources for the country, and they should highlight possible solutions, ensuring resource efficiency and development possibilities through industrial symbiosis.

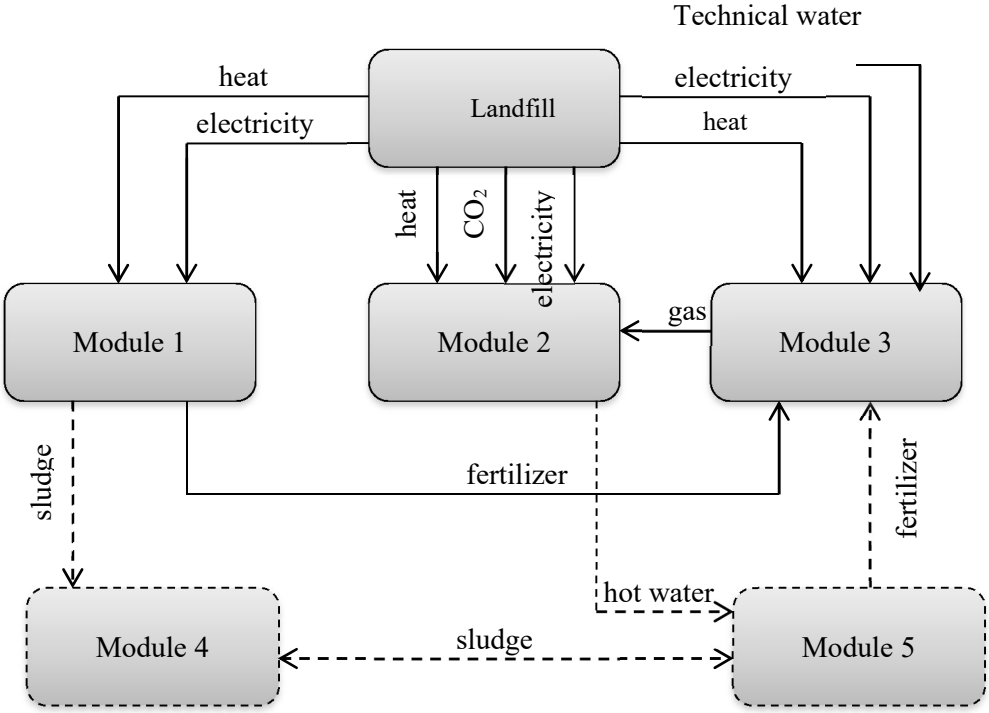


Figure 7. Industrial symbiosis model

Figure 7 depicts a possible industrial symbiosis model, offering cooperation between the modules. Based on this model, the landfill management company is able to choose the most suitable modules, which it can then construct, or a cooperation model with the desired industry could be offered. Further on, in developing the industrial symbiosis, other industries could join the symbiosis, not necessarily interacting directly with the landfill, but sharing resources with other modules.

In order to apply the resource balances to a particular landfill and thus choose the best possible solution, taking into consideration all the nuances and particularities of the landfill's operation, a decision-making matrix has been developed. This matrix will allow the landfill management company to take into account the main variables as well as its desired development path.

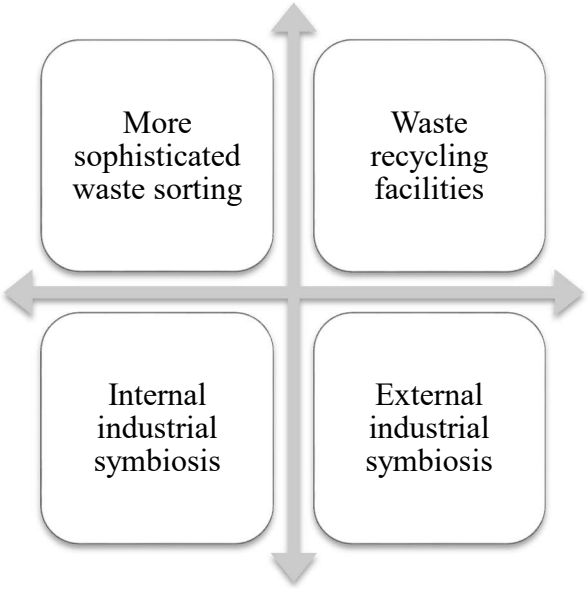


Figure 8. LMC matrix

Figure 8 offers a landfill management company decision-making matrix. It consists of four quadrants:

- The first quadrant, with preconditions of low volume of resources and low profit, foresees development in the form of modular internal industrial symbiosis. This means that the landfill management company has to balance the available resources and can choose one or a combination of modules suitable for industrial symbiosis.
- The second quadrant has the precondition of high volume of resources and low profit. This situation is considered to be a good starting point in order to develop more sophisticated waste sorting – focusing on smaller fractions with higher value (i.e. development of sorting of LDPE and HDPE and preparing this material in flakes / regrinds or pellets).
- The third quadrant foresees that a landfill management company has both high volume of resources and high profit. In this case it may consider focusing on

fractions, which can be imported for recycling from abroad and/or other Latvian waste management regions. These could be sophisticated tyre recycling facilities or specific material recycling facilities, which currently are not available in Latvia or nearby countries.

- The fourth quadrant, with low volume of resources and high profit, is suitable for a landfill management company that wishes to focus on sale of resources and development of infrastructure. In this case the company will be able to attract other industries and develop an industrial symbiosis centre.

Application of the LCM matrix will allow a landfill management company to identify its current position and future development prospective. Together with the industrial symbiosis model, developed in Figure 7, landfill management companies can apply the matrix and use these tools for decision-making and shifting towards the circular economy.

CONCLUSIONS

On the basis of the research undertaken, the authors have come to the following conclusions.

It is important to understand that the environment and entrepreneurship are in a constant conflict situation; a constant seeking for compromise in order to ensure fulfilment of environmental requirements alongside provision of company competitiveness and sustainable development is required.

In assessing the Latvian waste management system, a major contradiction has been identified: on the one hand current trends focus on sustainable use of resources and the necessity of decreasing landfilled waste volumes, and on the other hand landfill management companies are interested in as much incoming waste to landfills as possible, securing themselves with income. Elimination of this contradiction has social implications; a solution has to be found so that a decrease in incoming waste volumes would not increase the waste disposal rate several times and thus not influence inhabitants' fees for waste management.

System management in the waste management field in Latvia differs across regions and no unified approach has been developed, leaving waste management regions freedom of choice of one or another management model. Latvian landfill management companies can be divided into three groups, based on their activities (landfilling; landfilling and management of sorted waste; full cycle). Implementation of the model developed would allow landfill management companies, as expensive infrastructure elements, to ensure sustainable development and maintain an increase in waste disposal rates.

Assessment and management of the waste / resources generated on landfills, i.e. launching industrial symbiosis, could be an optimal solution, especially for landfill management companies engaged only in landfilling.

The present research provides landfill management companies with a landfill management company matrix, which facilitates decision-making in terms of choosing a company development strategy and initiating inter-sectoral cooperation.

The methodology developed allows for performing an in-depth analysis of reusable material flow at any stage of a landfill management company's development. Application of the methodology would allow for identifying particular reusable

resources, which would require more sophisticated preparation and for which this would be economically grounded.

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