TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 63, Issue Special, October, 2020

TECHNOLOGY SCOUTING FOR SOLID WASTE TREATMENT: TRIZ APPROACH

Pavel FIMIN, Evgenia SMIRNOVA, Oleg ABRAMOV

Abstract: *This paper presents a case study aimed at identifying and forecasting the most promising technologies for solid waste treatment, a problem that affects the entire world. To achieve this objective, the authors used a recently developed TRIZ Roadmap for Technology Scouting that employs such TRIZ tools as Main Parameters of Value (MPV) analysis, Voice of the Product (VOP), QEA-screening, and Trends of Engineering System Evolution (TESE) analysis. As a result of using this roadmap, it was found that the most promising technologies for solid waste treatment in the near future are those that involve gasification of waste at higher temperatures (up to 2000°C) in nearly anoxic conditions, which excludes combustion. The advantages of these technologies are: (1) they provide almost complete conversion of waste organics into synthesis gas, (2) they maximize recovery of metals, glass, and other secondary raw materials from inorganic residue, (3) they do not require careful preliminary sorting or sophisticated pre-treatment of waste, and (4) they are suitable for processing large volumes of waste (up to 1000 t / day). Additionally, the potential emissions of hazardous products, such as dioxins, furans and tar are eliminated, which means that these technologies can be implemented in residential areas, close to the final consumers of the generated synthesis gas and inorganic by-products. The TRIZ Roadmap for Technology Scouting used in this case study can be useful for finding technologies to solve other environmental problems, as it ultimately leads to effective solutions for saving and recycling all kinds of resources available in nature.*
Key words: *Function-Oriented Search, FOS, Main Parameters of Value, MPV, Quantum-Economic Analysis, QEA, Solid Waste Treatment, Technology Scouting, Trends of Engineering System Evolution, TESE, TRIZ, Voice of the Product, VOP.*

1. INTRODUCTION

The objective of this paper is to identify and forecast the most promising technologies for the global problem of solid waste treatment [1, 2]. This goal is justified by rapid population growth and urbanization [3], expanding waste generation due to increasing level of consumption [4], and numerous challenges associated with solid waste management [5].

A number of researchers have used TRIZ in order to address the problem of solid waste management [6-8], but for the most part they have used classical TRIZ tools, such as the Contradiction Matrix and Inventive Principles, to solve specific problems related to known technologies for waste processing. For example, Milisavljevic-Syed et al. [6] used these tools for improving the extraction of landfill gas; Swee et al. [7] used TRIZ to improve electronic waste management; and Russo, Peri, and Spreafico [8] used classical TRIZ to improve waste pyrolysis technologies.

Modern TRIZ, however, offers a new tool for identifying appropriate technologies and selecting the most promising of them. This tool is the TRIZ Roadmap for Technology Scouting proposed by the authors in a recent conference paper [9].

Technology scouting, which is widely used in industry, is divided into several categories. For example, Rohrbeck [10, 11] mentions three types of technology scouting that address different customer needs:

1. Technology monitoring, which is focused on the identification and assessment of information on technological developments in specific technological fields,

2. Technology scanning aimed at identifying new technological opportunities in white spaces not yet covered by the technological scope of the company, and
3. Technology sourcing that facilitates the provision of technological knowledge through joint research, licensing, buying intellectual property rights, creating joint ventures, or the direct acquisition of startups, etc.

The TRIZ Roadmap for Technology Scouting [9] covers item 2 on this list, which is in high demand in the practice of TRIZ-consulting because technology companies strive not only to maintain their technological leadership, but also to develop solutions for innovations that can provide them a competitive advantage in the future.

Unlike the Function-Oriented Search (FOS), introduced by Litvin [12] and traditionally used as a TRIZ tool for technology scouting, the TRIZ Roadmap [9] is easily applicable in situations when the original FOS is not very useful; for example, when the sought technology should or can only be found in the same industry for which it is wanted. This is a typical situation in, for example, the chemical industry when the objective is to find the most appropriate technology for the synthesis of some chemicals. Thus, it also applies to solid waste management.

Additionally, the TRIZ Roadmap for Technology Scouting not only identifies a set of technologies that can be adopted from remote areas, but it also recommends which of these technologies are most suitable for the customer, while the original FOS does not. Therefore, this tool was selected for identifying the most promising technologies for solid waste treatment.

2. METHOD: TRIZ-BASED ROADMAP FOR TECHNOLOGY SCOUTING

The TRIZ Roadmap for Technology Scouting [9] used in this case study is shown in Fig. 1. The roadmap assumes that the technology of interest has already been selected, which in our case is a technology for solid waste treatment.

As can be seen from Fig. 1, the roadmap utilizes several tools of modern TRIZ, such as Main Parameters of Value (MPV) analysis [13], FOS [12], Voice of the Product (VOP) [14, 15], Screening based on Quantum Economic Analysis (QEA-screening) [16, 17] and Trends of Engineering Systems Evolution (TESE) analysis [18].

As compared to the original FOS [12], the proposed roadmap provides a higher value of the results because it rejects unpromising technologies that cannot deliver the required MPVs, do not meet VOP, or unlikely to be commercialized by the client.

2. RESULTS

A brief, step-by-step explanation of the TRIZ Roadmap for Technology Scouting (Fig. 1) is presented below.

Step 1. Identifying MPVs.

The obvious basic MPVs that a solid waste treatment technology should deliver are:

- High performance – the ability to process over 100 tons of waste per day,
- High utilization of waste – after the completion of the process there should be no residual waste,
- Convenience for the consumer,
- Safety, and
- Relatively low cost.

In addition to this, an MPV analysis of the technologies currently in use for solid waste management [5, 6, 8, 19-24] revealed two less obvious latent MPVs, namely:

- The ability of technology to work with raw, unprocessed, and unsorted waste, and
- The ability to convert waste into secondary raw materials, higher value-added chemicals and fuels.

Step 2. Identifying leading areas for technology scouting: can technologies of interest be found outside the waste management area?

In this case, the technology of interest is definitely industry-specific, as waste processing is relevant only to the area of waste management. For solid waste management, therefore, the focus was only on existing technologies used in this area.

Step 1: Perform brief MPV analysis [13] and identify/clarify **client's MPV that the technology of interest should deliver**

Step 2: Identify whether the technology of interest is intended for
1. **Industry-specific operation/function** (e.g. in the chemical industry this could be the synthesis of a particular chemical product), or
2. A more general **operation/function used across several industries**

Step 3: If the technology is intended for performing an industry-specific operation/function, then **identify relevant technologies within the same industry;** when possible, group these technologies by the action principle
If the technology is intended for performing operation/function used across several industries, then use the original FOS [12] and identify **relevant technologies in the leading industries**

Step 4: **Reject** those **groups of technologies** that obviously **cannot deliver the required MPVs or cannot meet the constraints** that the client introduced

Step 5: Identify VOP [14] for the remaining technologies; **reject all technologies whose VOP does not meet voice of the customer (client) (VOC)** [15]

Step 6: Perform **QEA-screening** [16, 17] and reject those remaining technologies that are unpromising for the client in terms of business potential

Step 7: Benchmark the remaining technologies and **select the best one(s) in terms of current and potential performance** (use TESE [18] to assess potential performance)

Step 8: If necessary, **identify and solve adaptation problems** for the selected technology as in the original FOS [12]

Fig. 1. TRIZ Roadmap for Technology Scouting.

Step 3. Identifying relevant technologies.

All of the commercially available technologies for solid waste management can be divided into five large groups (see Fig. 2 for illustration):

1. Landfilling. This form of waste disposal, still the most common, especially in countries with abundant undeveloped land resources. The purpose of a landfill is to bury the waste in such a manner that it will be isolated from groundwater, will be kept dry and will not be in contact with air. Under these conditions, disposed waste will not decompose much.
2. Recycling. This involves separately collecting and recycling old paper, cardboard, glass, plastic, metal, etc.
3. Physico-mechanical treatment. In general, this is a multi-step process including crushing, magnetic and nonferrous sorting, air classification, grinding, and drying disposed waste. These process steps are aimed at separating from each other recyclable materials, biodegradable organic matter, and solid refuse fraction, which cannot be further recycled. From the latter, fuel for thermal power stations and cement kilns is produced.
4. Biological treatment. These technologies use naturally-occurring microorganisms to feed on the biodegradable portion of solid waste, converting them into simpler substances. This type of treatment is subdivided into two main categories: aerobic composting and anaerobic digestion.

a. Aerobic composting takes place in the presence of air in a humid and warm environment. In these conditions, organics of biodegradable waste are converted into compost (humus), having a high nutritional value.
b. Anaerobic digestion occurs in the absence of air at a temperature in the range of 20 to 70°C. In this case, a valuable product of biodegradable waste decomposition is biogas, which, due to its high methane content (up to 50-65% by volume), can serve as an alternative for fossil fuels

5. Thermal treatment. These processes can be accomplished by incineration, pyrolysis, and gasification.
   a) Incineration occurs at temperatures of 800-1450°C in excess air to ensure complete combustion. As a result, energy stored in the combustible components of waste is converted into the heat of flue gas (a mixture of carbon dioxide, steam, oxygen, and nitrogen). Owing to modern technologies, which allow, in principle, the removal of dioxins, benzo-furans, and other harmful components unavoidably generated during waste incineration [25], the heat of flue gases can be used, for instance, to produce steam for district heating and/or for generating electricity at thermal power stations [26].
   b) Pyrolysis takes place at relatively low temperatures compared to incineration (500-800°C) under anoxic conditions, which excludes combustion and, therefore, minimizes formation of hazardous waste decomposition products. In the course of pyrolysis, decomposing organics of waste can be converted into high-calorie synthesis gas, or syngas consisting predominantly of hydrogen and carbon monoxide, and into pyrolytic oil. After post-treatment, these products can be used to produce energy and/or industrial chemicals.
   c) Gasification commonly uses air, nitrogen, steam, carbon dioxide, or a mixture thereof as gasification agents and a low amount of oxygen (essentially below stoichiometric) to decompose waste. Nearly anoxic medium and enhanced temperature compared to pyrolysis (800-1500°C) provide a high yield of the syngas from organic matter of waste with a rather low level of harmful components.
   d) Plasma gasification. Even higher processing temperatures (1200-2000°C) are reached with plasma-assisted gasification. The heat energy of hot gases delivered by a plasma plume provides almost complete breakdown of dioxins, furans, tar, and other hazardous derivates of waste.

Step 4. Rejecting technologies that cannot deliver the identified MPVs.

At this step, Waste Landfilling was rejected because (1) it has negative health and environmental impacts, and (2) non-stabilized landfills contain a large number of recyclable materials that could be reused to minimize waste generation. Moreover, as mentioned Milisavljevic-Syed et al., landfill gas created by anaerobic decomposition of organic substances could be recovered from the landfill and used for energy production [6]. In other words, Landfilling does not provide the basic MPVs identified at Step 1.

Step 5. Rejecting technologies, whose VOP does not meet voice of the customer.

Based on the results of a VOP (in this case VOP means the voice of technology) analysis based on the TESE, Recycling, Physico-Mechanical Treatment, Biological Treatment, Incineration, and Pyrolysis were rejected.

Waste Recycling was rejected because it requires the active involvement of consumers to sort waste, which is necessary for efficient recycling. Moreover, the invention of new plastics suitable for Recycling further increases the number of waste streams to be managed. It is not surprising that the efficiency of Recycling remains low: 35% of paper and cardboard and 67% of glass are not recycled and, therefore, wasted [24]. The high involvement of consumers contradicts the Trend of Elimination of Human Involvement [18], and thus contradicts the VOP [14, 15].

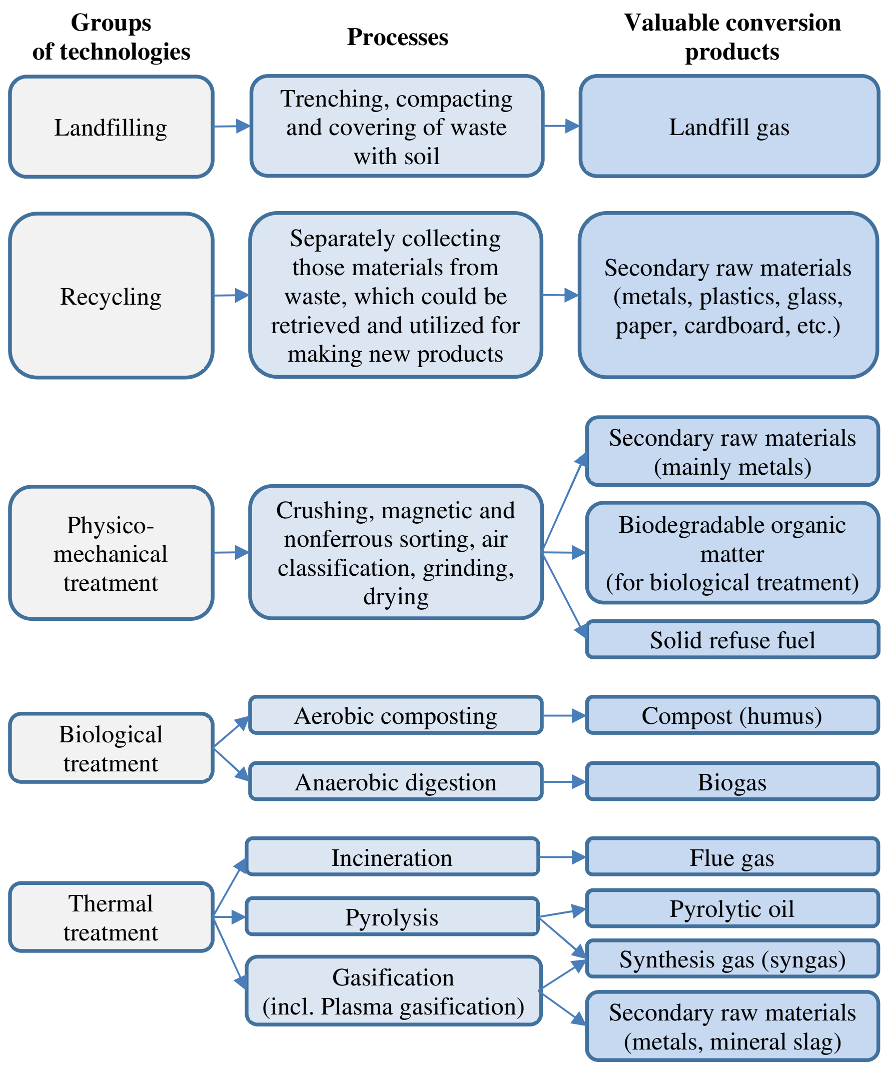

Fig. 2. Commercially available technologies for solid waste management

Physico-Mechanical Treatment, Aerobic Composting, Anaerobic Digestion, Incineration and Pyrolysis were rejected because these technologies are applicable only to limited categories of waste. In each of the processes mentioned, a series of providing operations are necessary to obtain waste fractions suitable for further treatment. Inadequate pre-treatment of the incoming waste material can lead to deterioration in effectiveness of the process and even to the failure of process equipment [21]. The inability of technology to work with unsorted and/or unprocessed waste contradicts the Trend of Increasing Ideality [18], and, therefore, again contradicts the VOP [14, 15].

For Physico-Mechanical Treatment, Incineration and Pyrolysis there is another problem that contradicts the Trend of Increasing Ideality. This is a large amount of solid residue. For instance, in incinerators of municipal solid waste, the bottom ash reaches up to 25-30% of the initial weight of solids [21]. These solids are typically sent to the landfill because their conversion into secondary raw materials is energy-consumable and quite costly.

Step 6. Performing QEA-screening.

Since there was no specific customer in this case study, the objectives of QEA-screening [16, 17] were to identify (1) what size the waste management company should be, and (2) how mature the waste management technology should be in order for the waste management business to be successful.

The waste management market was assumed to be at the second or third level of its development since most nations are already using some form of waste management.

Based on this, the following important results were obtained:

1. A successful waste management company should be large or medium-sized.
2. A successful waste management technology should be mature – close to its third stage on the S-curve. Remaining technologies (Non-plasma and Plasma Gasification) in this case study meet this requirement, and, therefore, pass QEA-screening.

Step 7. Benchmarking the remaining technologies.

Benchmarking the remaining technologies revealed that the best one for solid waste treatment is Plasma Gasification. The key benefits of this technology are the following:

1. It provides almost complete conversion of waste organics into synthesis gas with a negligible emission of dioxins, benzo-furans, tar, and other hazardous derivates of waste,
2. It maximizes recovery of metals, glass, and other secondary raw materials from the inorganic fraction of waste, and
3. It does not require careful preliminary sorting or sophisticated pre-treatment of waste.

Step 8. Identification of adaptation problems.

Examples of adaptation problems that have to be solved in order to use gasification technologies for solid waste treatment are:

- How to make the composition of incoming solid waste uniform even as it changes from batch to batch?
- How to use the inorganic slag generated as a by-product during gasification?

Although solving these adaptation problems is beyond the scope of this work, it is clear that any or all TRIZ problem solving tools may be applied for this purpose.

4. LEADING TECHNOLOGY: EXAMPLE OF COMMERCIAL APPLICATION

Currently, there are a number of commercial facilities that use plasma gasification for solid waste treatment [27]. In this section, as an example, the technological process developed by Westinghouse Plasma Corporation (Madison, USA) is briefly considered [28]. Currently, this technology is capable of processing waste volumes up to 1000 t / d [29].

The process scheme is presented in Fig. 3. The feedstock, which can be municipal solid waste, biomass, medical waste, hazardous waste, waste tires, etc., is fed into a gasification reactor and falls at the bottom by gravity. Input heat energy into the reactor is provided by four plasma torches. An additional source of energy for heating waste is coke covering the bottom of the reactor. The bulk temperature within the base of the reactor is about 2000°C. It is more than sufficient to almost completely break down higher molecular components of waste into main constituents of syngas: hydrogen and carbon monoxide.

The syngas leaves the reactor at the temperature in the range of 890-1100°C. Then it goes through a series of cleaning processes to remove particulate matter, volatile heavy metals, gas-phase halides, as well as compounds of sulfur and nitrogen.

The molten inorganic slag exits the reactor at a temperature of 1650°C through the tap holes at the bottom of the reactor. On exiting the reactor, the slag is quenched and granulated, and then undergone a magnetic separation to separate the ferrous metal from the mineral slag.

In summary, out of every 1000 tons of processed waste, only 20 tons of particulate matter and 20 tons of sludge are sent for landfilling or recycled back into the plasma gasifier.

5. CONCLUSION

The results of this work show that the TRIZ Roadmap for Technology Scouting is easily applicable to the problem of solid waste treatment. It was also ascertained that:

1. The most promising technologies to treat solid waste in the near future are those that

involve gasification of waste at higher temperatures (up to 2000°C) in nearly anoxic conditions, which excludes combustion;

2. To be successful in the waste management business, the company utilizing these technologies needs to be large or medium-sized.

The advantages of the most promising technologies identified are:

- They provide almost complete conversion of waste organics into synthesis gas with a negligible emission of hazardous constituents such as dioxins, furans, tar, etc.
- They maximize recovery of metals, glass, and other secondary raw materials from the inorganic fraction of waste,
- They do not require careful preliminary sorting or sophisticated pre-treatment of waste, an
- They are suitable for processing large volumes of waste (up to 1000 t / day), and
- Therefore, these technologies can be implemented in residential areas, close to the final consumers of the generated synthesis gas and by-products of the solid waste treatment.

As a final point, the case study revealed two adaptation problems that need to be addressed in order for these technologies to be widely adopted.

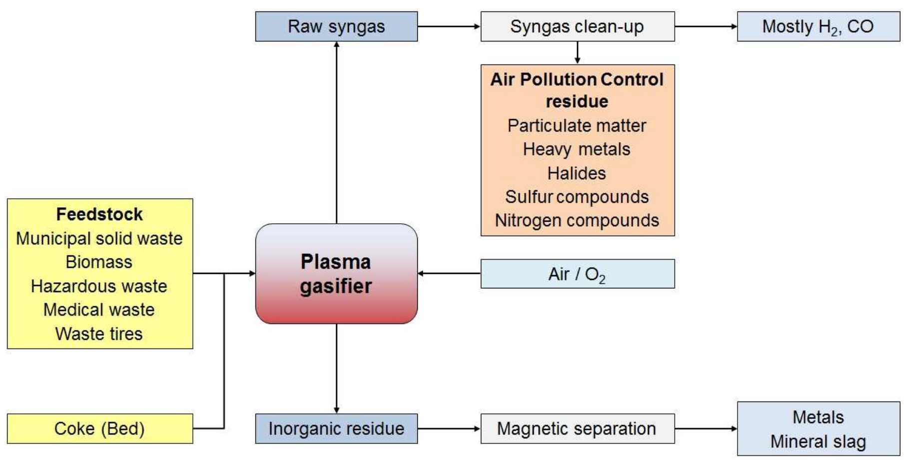

Fig. 3. Plasma gasification for solid waste treatment.

In summary, out of every 1000 tons of processed waste, only 20 tons of particulate matter and 20 tons of sludge are sent for landfilling or recycled back into the plasma gasifier.

5. CONCLUSION

The results of this work show that the TRIZ Roadmap for Technology Scouting is easily applicable to the problem of solid waste treatment. It was also ascertained that:

3. The most promising technologies to treat solid waste in the near future are those that involve gasification of waste at higher temperatures (up to 2000°C) in nearly anoxic conditions, which excludes combustion;
4. To be successful in the waste management business, the company utilizing these technologies needs to be large or medium-sized.

The advantages of the most promising technologies identified are:

- They provide almost complete conversion of waste organics into synthesis gas with a negligible emission of hazardous constituents such as dioxins, furans, tar, etc.

- They maximize recovery of metals, glass, and other secondary raw materials from the inorganic fraction of waste,
- They do not require careful preliminary sorting or sophisticated pre-treatment of waste, an
- They are suitable for processing large volumes of waste (up to 1000 t / day), and
- Therefore, these technologies can be implemented in residential areas, close to the final consumers of the generated synthesis gas and by-products of the solid waste treatment.

As a final point, the case study revealed two adaptation problems that need to be addressed in order for these technologies to be widely adopted.

8. REFERENCES

[1] O'Connell, E.J.: *Increasing public participation in municipal solid waste reduction.* The Geographical Bulletin 52(2), 105–118 (2011).

[2] Samiha, B.: *The importance of the 3R principle of municipal solid waste management for achieving sustainable development.* Mediterranean Journal of Social Sciences 4(3), 129–135 (2013).

[3] Ritchie, H., Roser, M.: *Urbanization. Published online.* (2018). Available at: https://ourworldindata.org/urbanization, last accessed 2020/05/31.

[4] Geyer, R., Jambeck, J.R., Law, K.L.: *Production, use, and fate of all plastics ever made. Science Advances 3(7)*, e1700782 (2017).

[5] Joshi, R., Ahmed, S.: *Status and challenges of municipal solid waste management in India: A review.* Cogent Environmental Science 2(1), 1139434 (2016).

[6] Milisavljevic-Syed, J., Tomić, M., Marković, D., Miltenović, V.: *Application of the TRIZ method for selecting thermal treatment procedure and obtaining energy from waste.* Facta Universitatis – Series Mechanical Engineering 8(1), 77–88 (2010).

[7] Swee, N., Yip, M., Chee Sheng, K., Tai, S., Toh, G.: *Managing E-waste using TRIZ.* International Journal of Electronics and Electrical Engineering 1(1), 19–22 (2013).

[8] Russo, D., Peri, P., Spreafico, C.: *TRIZ applied to waste pyrolysis project in Morocco*. In: Benmoussa R., De Guio R., Dubois S., Koziołek S. (eds.) New Opportunities for Inno-vation Breakthroughs for Developing Countries and Emerging Economies. 19th International TRIZ Future Conference, TFC 2019, pp. 295–304. Springer, Cham (2019).

[9] Abramov, O., Fimin, P., Smirnova, E.: *Technology scouting in chemistry: roadmap and case studies.* In: Proceedings of the 15th MATRIZ TRIZfest International Conference, pp. 319–326. Heilbronn, Germany (2019).

[10] Rohrbeck, R.: Technology Scouting – a case study on the Deutsche Telekom Laboratories. In ISPIM–Asia Conference 2007, New Delhi, India (2007). Available at SSRN web site: https://ssrn.com/abstract=1896150, last accessed 2020/05/28.

[11] Rohrbeck, R.: *Harnessing a network of experts for competitive advantage: technology scouting in the ICT industry.* R&D Management 40(2), 169–180 (2010).

[12] Litvin, S.: New TRIZ-Based tool Function-Oriented Search (FOS). In: Castini, G. (eds.) TRIZ Future Conference 2004, vol. 16, pp. 505–508. Firenze University Press, Firenze, Italy (2004).

[13] Litvin, S.: *Main Parameters of Value: TRIZ-based tool connecting business challenges to technical problems in product/process innovation.* PowerPoint presentation for the workshop at 7th Japan TRIZ Symposium. Yokohama, Japan (2011). Available at Japan TRIZ Society web site: http://www.triz-japan.org/PRESENTATION/sympo2011/Pres-Overseas/EI01eS-Litvin_(Keynote)-110817.pdf, last accessed 2020/05/28.

[14] Abramov, O.Y.: *Product-oriented MPV analysis to identify Voice of the product.* In: Proceedings of the 12th MATRIZ TRIZfest International Conference, pp. 231–243. Beijing, People's Republic of China (2016).

[15] Abramov, O.Y.: *'Voice of the Product' to supplement 'Voice of the Customer'*. . In:

Proceedings of the 11th MATRIZ TRIZfest International Conference, pp. 309–317. Seoul, South Korea (2015).
[16] Abramov, O.Y.: *Generating new product ideas with TRIZ-derived 'Voice of the Product' and Quantum-Economic Analysis (QEA)*. Journal of the European TRIZ Association IN-NOVATOR 4(2), pp. 80–87 (2017).
[17] Abramov, O., Markosov, S., Medvedev, A.: *Experimental validation of Quantum-Economic Analysis (QEA) as a screening tool for new product development.* In: Koziołek, S., Chechurin, L., Collan M. (eds.) Advances and Impacts of the Theory of Inventive Problem Solving, pp. 17–25. Springer, Cham (2018).
[18] Lyubomirskiy, A., Litvin, S., Ikovenko, S., Thurnes, C., Adunka, R.: *Trends of Engineering System Evolution (TESE): TRIZ paths to innovation.* TRIZ Consulting Group (2018).
[19] Freudenrich, C.: *How landfills work. Published online (2000).* Available at: https://science.howstuffworks.com/environmental/green-science/landfill.htm, last accessed 2020/08/13.
[20] Jenkins, S.D., Legrand, R.: *Conversion technologies: A new option for MSW management.* In: Proceedings of the 13th Annual North American Waste to Energy Conference (NAWTEC13-3153), pp. 55–61. Orlando, FL, USA (2005).
[21] Bosmans, A., Vanderreydt, I., Geysen, D., Helsen, L.: *The crucial role of Waste-to-Energy technologies in enhanced landfill mining: a technology review.* Journal of Cleaner Production 55, 10–23 (2013).
[22] Pieta, I.S., Epling, W.S., Kazmierczuk, A., Lisowski, P., Nowakowski, R., Serwicka E.M.: *Waste into fuel – catalyst and process development for MSW valorisation.* Catalysts 8(3), 113 (2018).
[23] *Options for the treatment of principal fractions of the municipal waste considering the local framework.* In: Bilitewski, B., Wagner, J., and Reichenbach, J. (eds.) Best Practice Municipal Waste Management, pp. 29–44. Umweltbundesamt, Dessau-Roßlau (2018).
[24] Ferrari, M.: *Is plasma gasification the solution for plastics and all waste?* Published online (2020). Available at: https://www.plasticstoday.com/packaging/plasma-gasification-solution-plastics-and-all-waste/181263217161321, last accessed 2020/06/05.
[25] Mukherjee, A., Debnath, B., Ghosh, S.K.: *A review on technologies of removal of dioxins and furans from incinerator flue gas.* Procedia Environmental Sciences, 35 528–540, (2016).
[26] Eriksson, O., Finnveden, G.: *Energy recovery from waste incineration – the importance of technology data and system boundaries on CO2 emissions.* Energies 10(4), 539, (2017).
[27] Byun, Y., Cho, M., Hwang, S. M., Chung, J.: *Thermal plasma gasification of municipal solid waste (MSW).* Gasification for Practical Applications, 183–210 (2012).
[28] The Alter NRG / *Westinghouse Plasma Gasification Process.* Independent Waste Technology report. Juniper Consultancy Services Limited, Bathurst House, Bisley, UK (2008).
[29] Nicolae, B.: *Plasma gasification the Waste-to-Energy solution for the future.* Problemele Energeticii Regionale 3(26), 107–115 (2014).

Cercetarea tehnologiei pentru tratarea deșeurilor solide: abordare TRIZ

Rezumat: Această lucrare prezintă un studiu de caz care vizează identificarea și prognozarea celor mai promițătoare tehnologii pentru tratarea deșeurilor solide, o problemă care afectează întreaga lume. Pentru a atinge acest obiectiv, autorii au utilizat instrucțiuni TRIZ recent dezvoltate pentru

cercetarea tehnologică, care folosesc instrumente TRIZ precum analiza parametrilor principali ai valorii (MPV), vocea produsului (VOP), validarea QEA și analiza tendințelor evoluției sistemelor de inginerie (TESE). Ca urmare a utilizării acestor instrucțiuni, s-a constatat că cele mai promițătoare tehnologii pentru tratarea deşeurilor solide în viitorul apropiat sunt cele care implică gazificarea deșeurilor la temperaturi mai ridicate (până la 2000ºC) în condiții aproape anoxice, ceea ce exclude arderea. Avantajele acestor tehnologii sunt: (1) ele oferă conversia aproape completă a deșeurilor organice în gaze de sinteză, (2) maximizează recuperarea metalelor, sticlei și a altor materii prime secundare din reziduurile anorganice, (3) nu necesită sortarea prealabilă sau pre-tratarea sofisticată a deşeurilor şi (4) sunt adecvate pentru prelucrarea volumelor mari de deșeuri (până la 1000t/zi). În plus, emisiile potențiale ale produselor periculoase, precum dioxine, furani și gudron sunt eliminate, ceea ce înseamnă că aceste tehnologii pot fi implementate în zone rezidențiale, aproape de consumatorii finali, ai gazelor de sinteză și de produsele secundare anorganice. Instrucțiunile TRIZ pentru cercetarea tehnologică folosite în acest studiu de caz pot fi utile pentru a găsi tehnologii care să resolve alte probleme de mediu, deoarece în cele din urmă duce la soluții eficiente pentru economisirea și reciclarea tuturor tipurilor de resurse disponibile în natură.

Pavel FIMIN, PhD, Algorithm Ltd., St. Petersburg 190013, Russia, pavel.fimin@algo-spb.com
Evgenia SMIRNOVA, Algorithm Ltd., St. Petersburg 190013, Russia, evgenia.smirnova@algo-spb.com
Oleg ABRAMOV, PhD, Algorithm Ltd., St. Petersburg 190013, Russia, oleg.abramov@algo-spb.com