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The importance of logistics in the circular economy of agricultural enterprises

Martyna Kacprzak
University of Zielona Góra, Faculty of Economic and Management, Podgórna 50, 65-246 Zielona Góra, Poland, EU, martyna.kacprzak3@wp.pl (corresponding author)
Maciej Kozaryn
University of Zielona Góra, Institute of Management and Quality Sciences, Podgórna 50, 65-246 Zielona Góra, Poland, EU, m.kozaryn@wez.uz.zgora.pl
Mateusz Kurowski
University of Zielona Góra, Institute of Management and Quality Sciences, Podgórna 50, 65-246 Zielona Góra, Poland, EU, m.kurowski@wez.uz.zgora.pl

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Abstract: The article is intended to show the role of logistics in the circular economy. This is because it encompasses the actual flow of products from their source of production to the final consumer, taking into account all the tasks and activities involved, ensuring efficient, sustainable and economic processes. Circular economy aims to maximise product value through eco-design, increased sustainability, improved quality, eco-efficiency and the widespread use of renewable materials. This approach promotes waste reuse, recycling and recovery, as well as treating waste as a valuable resource. The agricultural industry deserves special attention in the context of the circular economy, so improvements have been proposed to change the agricultural enterprise to a greener and more practical one that applies the principles of the circular economy. Thus, biogas production, the transportation of slurry via pipeline system and the creation of an on-site photovoltaic panel farm were suggested. The application of these improvements could make the company independent and use only its resources. Furthermore, by using renewable energy sources, the company could increase its competitiveness in the market, become an independent entity and reduce its operating costs, all while increasing its efficiency.

1 Introduction

In the face of modern environmental challenges, the circular economy (CE) is gaining increasing importance as a model of sustainable development. The concept involves minimising waste and maximising available resources, thus finding its way into various economic sectors, including the agricultural industry. Agricultural companies, due to the nature of their business and their direct impact on the environment, are particularly committed to implementing CE practices. Logistics plays a key role in the implementation of the circular economy, enabling the efficient management of resources, waste, recycling and distribution of products in a sustainable manner. In the context of agricultural enterprises, it contributes to optimising production processes, reducing waste and improving operational efficiency.

The aim of this paper is to assess the role of logistics in supporting the implementation of the CE concept in agricultural enterprises, with particular reference to the solutions proposed to Grolder Sp. z o.o. The following research questions are presented: What logistics solutions can support the implementation of the circular economy in agricultural enterprises? What impact does the practical application of the circular economy concept have on the logistical processes implemented by agricultural enterprises? To find answers for these questions, observations and analysis of various factors were made. The article is based on a literature analysis, case studies and interviews with experts from the agricultural and logistics industry.

2 Logistics and the circular economy

Logistics plays a key role in the CE, as it is essential to the efficient, sustainable and economic operation of the circularity in question. Logistics, in its broadest sense, refers to "the processes of the real flow of products from the sources of acquisition from nature to the marginal links that satisfy the consumer needs of households and the production and investment needs of economic actors" [15]. In the literature, the circular economy is defined as "maximising the added value of products in the value chain by, among other things. introducing eco-design, taking into account the whole life cycle of the product, increasing sustainability, increasing quality, cascading products, eco-efficiency of processes, promoting cooperation in the value chain (economic symbiosis), sharing, widespread use of renewable materials, virtualisation" [9] and as "minimising waste through reuse, recycling and the implementation of full recovery, including above all treating waste - if it arises - as a potential source of secondary raw materials, often not available in the EU due to lack of resources (critical raw materials), widespread use of waste heat or reuse of water" [10]. Logistics supports the basic tenets of CE by effectively managing resources and waste, minimising

waste and costs and maximising the reuse of materials. It also enables the tracking and management of the flow of raw materials, semi-finished and finished products in a way that minimises waste and optimises the use of available resources [8]. In a circular economy, the key is precisely to keep materials in circulation for as long as possible [12]. An important part of logistics is transport, which involves defining routes, their regularity and choosing the right system and the right mode of transport to reduce emissions, including CO_2 and operating costs [2]. Adequate management of the storage and distribution of products and materials is essential to ensure that they are available when they are needed, and that they do not sit unnecessarily in storage, which could lead to them being wasted - the concept of logistics in the broadest sense is also behind these activities. All the tasks in question are accompanied by continuous supervision and control, i.e. information and decision-making processes are present at all times in the execution of the individual goals. The entire process is monitored and checked in real time [16]. Checks are made to ensure that all standards and regulations are being complied with, especially those relating to environmental protection and the safety of people working at a particular stage. Various analyses and reports are collected and used to optimise the processes that are in place all the time and to plan future activities that will make the various stages operate more efficiently and benefit from reduced environmental impact [5].

An important point in the circular economy is waste, which according to its principle should be treated as a valuable resource that can be reintroduced into the production cycle. Here, it is logistics that is behind the organisation of waste collection, sorting and transport of materials for recycling and processing. With the right logistics solutions, any recycling and reuse of materials can be managed efficiently. Logistics processes are responsible for the storage and processing of waste. In addition, they manage temporary waste storage sites and the landfills themselves. Logistics is also related to the issue of organising waste treatment processes, including recycling, composting, incineration and energy recovery. It includes the management of the different types of containers and bins that are used to collect and transport waste, with responsibility for their delivery, replacement and maintenance [3]. Logistics is a key tool to minimise costs throughout the waste management process as well as throughout the supply chain, as it helps to reduce costs by optimising operations, planning efficient routes, minimising waste and monitoring performance. Logistics is an integral element in the pursuit of sustainability, as it is through logistics that efficient waste management takes place. It therefore contributes directly to the sustainable development goals of environmental protection, reduction of greenhouse gas emissions and appropriate waste treatment. If conducted correctly, it also ensures safety and health for people and regulates regulations and procedures. All the aspects of circular economy logistics discussed are important for the efficient and sustainable management of available resources [17]. Cooperation between suppliers, manufacturers, distributors and recyclers allows for more efficient resource management and waste minimisation. In summary, logistics is the foundation on which the circular economy is based. With efficient and sustainable logistics solutions, companies can better manage resources, reduce their environmental impact and support sustainable development.

3 Challenges faced by modern farms

Agriculture includes arable farming and animal husbandry, horticulture, vegetable farming, forestry and inland fisheries, as well as related transport, handling, processing and sales [13]. Farming is a complex activity and highly dependent on nature, weather conditions and other factors beyond human control. Agriculture is seasonal, which means that individual wastes are generated over a short period of time, but intensively, and this can complicate and hinder their management. Farmers need to effectively manage available resources such as artificial and natural fertilisers, agricultural machinery and equipment, as well as water, soil or air, as their poor management can cause groundwater contamination, lead to soil erosion and generate hazardous waste through poor crop planning. The frequent use of pesticides by agricultural workers in the fields should be considered as generating toxic substances, as they are the ones that, which when used, become chemical waste that pose a risk to health and the environment itself. Agriculture depends heavily on energy and fossil fuels for the agricultural machinery that is used every day to work in the fields or with the animals. This generates significant greenhouse gas emissions and waste associated with the maintenance of agricultural machinery and vehicles.

At this point in time, many agribusinesses have begun to engage in caring for the environment and sustainability. In their operations, depending on their specifications, they are taking different steps and actions that benefit the ecosystem. In addition, there is a strong emphasis on the creation and use of renewable energy sources, in view of the enormous air pollution and the running out of fossil fuels or rising fuel and electricity prices. Farms that want to become more environmentally friendly and modern face numerous challenges in adapting to pro-environmental changes and implementing a CE concept. First and foremost, farms need to reduce the consumption of the resources they use, such as water or electricity. To do this, companies are using renewable energy sources - solar panels and wind turbines to power the farms.

Those in the agricultural sector have to produce sustainably, depending on their crop or livestock activities, which means they have to manage the available products properly during production, including reducing the generation of waste and greenhouse gas emissions. For such a specific sector, this involves appropriate crop rotation, i.e. the use of crop rotation, intercropping and

organic farming, which aims to protect the soil and its biodiversity. Another important aspect is the management of manure, which is a hazardous waste. The organic residues that are generated in companies should be diverted according to sustainability, which means composting them and converting them in biogas plants into energy and fertilisers. Companies need to introduce a proper waste separation system, using compost and manure as natural fertilisers. Today, agricultural companies are beginning to use GPS technology for field work and drones to monitor and manage crops in order to optimise resource consumption. Education and environmental awareness provided to entrepreneurs and their employees is also important. Training should be organised on how to conduct and maintain sustainable agriculture and CE practices, and awareness should be raised about the benefits of implementing environmentally friendly practices. The sector is constantly changing, due to a variety of factors.

The impact of economic and political events over the last few decades has changed this sector. Accession to the European Union has had a huge impact on this economic sector, as it has provided it with access to financial resources, which in turn have enabled and accelerated the process of modernisation of farms and allowed it to adapt to new market conditions. As a result of sustainability and environmental protection measures, the conditions and rules of operation are constantly changing. Today, environmental protection is a priority in European Union policy and one of the greatest and most important challenges. Concern for nature, its state and the public good is making regulations more and more stringent in terms of compliance. Agricultural enterprises also have operational requirements to comply with environmental protection [6]. The agricultural sector is therefore covered by a number of documents that specify how waste generated in this sector is to be dealt with, as the majority of waste generated in this sector is hazardous waste, which must be dealt with in a special manner as it has specific handling guidelines. This involves the appropriate optimisation of economic processes and handling methods in order to reduce and change the bad impact of the agricultural sector [14]. Farmers can implement a range of innovations into their businesses that are able to improve production and farm productivity. Adapting to pro-environmental changes not only protects the environment, but also increases competitiveness in the market, resulting in more sustainable and efficient farming.

Implementing a circular economy requires a holistic approach, meaning that all elements are interconnected and influence each other, creating a single system that combines activities at different levels. Agricultural enterprises that successfully adapt to green changes can not only contribute to environmental protection, but also increase their operational efficiency and competitiveness in the market.

4 Logistics in an agricultural enterprise implementing the circular economy concept - examples of solutions and benefits of proposed improvements

Grolder Sp. z o.o. is a company engaged in crop and livestock production. It is an agricultural company that engages in the cultivation of agricultural land and industrial pig rearing. This rearing is a production method in which, according to an established technology, the same production processes are repeated in specific time cycles. The industrial pig farm is a closed-cycle facility, where the rearing period covers all phases of the animal's life. Grolder therefore belongs to the agricultural sector and has 644 ha of farmland, including twelve tractors. Due to the nature of their business, they mostly grow sunflower, rape, barley, triticale and wheat. The company has twelve livestock buildings, or piggery, housing more than 26,000 pigs and comprising piglets and sows. In addition, there are five other buildings necessary for the operation, including administrative and social buildings and various installations needed for the operation of the company.

In order to improve the company's existing operations, it has been proposed to produce biogas, to transport slurry using a pipeline system instead of tractors and to create a photovoltaic panel farm on the site [7]. The waste with the largest mass that is produced on the company's premises is animal manure. The idea of how to use it efficiently was born. The construction of a biogas plant can serve as an alternative energy source, i.e. biogas. According to the definition of agricultural biogas, it is understood to be "a gaseous fuel obtained from agricultural raw materials, agricultural by-products, liquid or solid animal excreta, by-products or residues from the agri-food industry or forest biomass through methane fermentation" [19]. Biogas processing is a process that occurs under anaerobic conditions and involves the decomposition of organic materials such as plant residues, manures or sewage sludge into gas. The main product that arises from this reaction is methane, which can be used in the company as an energy source. The biogas collected is processed and could then be used precisely for the production of electricity and heat, as well as a fuel to power agricultural equipment [1]. Investing in biogas could realistically bring a lot of benefits to the company, as it is a renewable energy source that fits into a CE and offers the opportunity to process a waste product such as slurry, which is largely generated on site, and allows plant waste to be converted into heat and energy, while also creating a substrate that is better for fertilising soils than manure or slurry. From data obtained from the company, 25,911.4 tonnes of slurry were generated in 2022. Assuming, therefore, that one has a slurry volume of around 26,000 tonnes per year, it is necessary to calculate how much biogas can be produced per year. From the available data it is known that about 20 cubic metres of biogas can be obtained from 1 tonne. So:

$$26\,000\ t\ slurry \times 20\frac{m^3}{t} = 520\,000\ m^3\ biogas\ per\ year$$

Another aspect that is known is the average calorific value of biogas, which is approximately 25 MJ/m^3, thus:

$$52\,000\ m^3 \times 25\frac{MJ}{m^3} = 13\,000\,000\ MJ\ per\ year$$

Converting 13 000 000 MJ into kWh results in 3 611 100 kWh. By combining the data obtained from the company and the annual output of the biogas plant, the result is that the company's electricity needs are covered.

Table 1 Summary data for 2022-2023 on the amount of electricity consumed and costs

	2022	2023
Amount of electricity consumed [kWh]	1 017 280	1 119 210
Cost [PLN]	909 920.72	1 228 345.39

To estimate the investment cost (Table 1), costs such as: infrastruktura – zakup lub zmiana przeznaczenia ziemi pod budowę biogazowni, budynków, placów, drogi dojazdowej:

- infrastructure – purchase or change of land use for the biogas plant, buildings, yards, access road;
- technology – the purchase or construction of biogas production facilities, including fermenters, substrate tanks, biogas recovery systems, monitoring and control systems;
- raw materials – the purchase or transport of organic raw materials that will be used for biogas production;
- labour – salaries for the company constructing the biogas plant and salaries for the staff responsible for the operation and maintenance of the biogas plant;
- regulations and legislation – obtaining the necessary permits, certifications, environmental studies and safety audits;
- energy – costs associated with powering the biogas plant, including the consumption of electricity and heat needed to operate the equipment;
- maintenance and repair – costs of regular maintenance of the equipment and possible repairs and upgrades;
- finance – the loan or grant taken out.

The cost of the investment would be estimated at around PLN 10 million, due to the aforementioned costs, details of which for individual cost items are not public. The time after which the investment would pay off was calculated on the basis of available data:

- investment outlay: 10 000 000 PLN;
- annual energy value: PLN 1,228,345.39;
- operating costs per year: PLN 556 328.76.

Calculation of net operating value per annum:

$$1\,228\,345.39\ PLN - 556\,328.76\ PLN = 672\,016.63\ PLN$$

Calculation of the payback period:

$$10\,000\,000\ PLN \div 672\,016.63\ PLN \approx 14.88\ years$$

The time period in which the investment in a biogas plant will pay off, under current assumptions, is approximately 14/15 years.

Due to its operations and needs, the company consumes more and more fuel (Table 2) and has to incur significant costs. The main factors that influence this are the political, economic and business situation in the country. The price of oil has recently increased significantly, by around 65% since 2020.

Table 2 Summary data for 2020-2023 on the amount of fuel consumed and costs

	2020	2021	2022	2023
Number of agricultural hectares [ha]	594	644	644	644
Cost [PLN]	243 797.91	243 952.07	348 617.50	438 170.62
Amount of fuel consumed [l]	60 392	65 607.35	67 246	70 457

As previously mentioned, the company owns agricultural machinery for its own use, which is powered by internal combustion engines and is used for sowing and harvesting crops. The company is constantly investing, but currently also owns older models of tractors that still fulfil their role, but they are less efficient compared to newer and more modern models that are more technologically efficient and in terms of the fuel they consume. The company is a huge farm with 644 hectares in agricultural use, and this contributes to more machine work and results in increased fuel consumption. An unploughed system is used on the fields, which is more efficient compared to the ploughed system, which carries a negative impact in terms of the soil itself, the environment and the harvest result itself. The system used is more sustainable as it reduces soil erosion, which directly contributes to the storage of water in the soil and, importantly, reduces fuel consumption [11]. In order to reduce the amount of fuel used and energy costs and to reduce emissions of CO_2 and other toxic substances, slurry transport through a pipeline system can be used. This system is a technology by which slurry is transferred via pipes from the storage area, in this case the lagoon, to the fields. This method is a more efficient way of applying organic manure than traditional methods using tractors, as it distributes the slurry more precisely [19]. To start with, a company could invest in spreading such a system on 100 ha of fields. Additionally, it would save drivers' time, as

there is also no need to wait for loading or unloading and washing. The system can be managed remotely, which reduces the risk of human error and increases reliability. The driver's working time for spreading slurry takes 16 hours, which saves 32 hours over a year, as twice a year slurry removal takes place, therefore saving four days of employee work. By setting up the system on all fields, the company could increase its efficiency. Most of the fields, about 560 ha, are within the farm, by installing the system in question agricultural machinery would then not be involved in fertilising the fields. The fuel consumption and costs to the enterprise were analysed (Table 3).

Table 3 Summary data for 2022-2023 on fuel consumption volumes and associated costs

	2022	2023
Amount of fuel used [l]	67 246	70 457
Cost [PLN]	348 617.50	438 170.62

It should be noted that the company consumes more than 70 000 litres of fuel. Assuming that the average fuel consumption of the tractor is 10 litres per hour and the average operating time of the tractor on one tank of fuel is 8 hours. This means that the tractor will consume 80 litres of fuel during 8 hours of operation. If an employee works for 16 hours the fuel consumption will be 160 litres. The export takes place twice a year so 320 litres - just for 100 ha.

The cost of the investment is approximately PLN 150 000. Included here are costs such as (details for individual items are not public):

- materials – pipe, fittings, valves, pumps, filters, casing, etc. depending on the type of materials and pipe diameter, costs can vary considerably;
- labour and services – the cost associated with the installation work: employing a company to install the pipeline and the cost of hiring heavy equipment to excavate and lay the pipe;
- engineering and design – the design of the pipeline system by engineers, including the cost of consultancy, field surveys, creation of design documentation, etc.;
- survey and testing – carrying out leakage tests, pressure measurements, checking system performance, etc.;
- regulations and legislation – obtaining necessary permits, notifications, and costs related to environmental and safety compliance and regulations;
- repair and maintenance – regular maintenance, repair and possible upgrading of the pipeline system.

The time after which the investment would pay off was calculated on the basis of available data:

- investment outlay: PLN 150 000,
- annual savings: PLN 30 000 (fuel costs and staff time costs are included here).

Payback period calculation:

$$150\,000\ PLN \div 30\,000\ PLN = 5\ years.$$

The expected return on investment could occur after about five years due to reduced fuel consumption and the salaries of the workers who would have to be paid for their work and maintenance of the equipment. Investing in a slurry spreading system would reduce the costs that currently need to be incurred, in addition to reducing diesel consumption and environmental pollution from toxic substances emitted into the air by agricultural machinery and equipment, while increasing overall energy efficiency [20].

In an effort to continually improve the company's cost-saving and environmental performance, the company is proposing a small change to its electricity consumption and thus reduce costs by setting up a photovoltaic panel farm. This is a long-term investment that will pay off over time through savings in energy costs. Photovoltaic panels, also known as photovoltaic modules, are devices that convert light energy, usually from the sun, into electrical energy [4]. It is a renewable energy technology that is growing in popularity due to its many benefits. The panel consists of photovoltaic cells, usually made of silica. When sunlight falls on the panel, electrons are released, which in turn generates an electric current [18]. Tapping into this renewable energy source could result in the company generating its own electricity and even selling it. The number of panels needed by the company to cover the costs associated with electricity consumption was calculated. Initially, it was necessary to convert the amount of electricity consumed into power:

$$1\,119\,210\ kWh \div 8760\ h \approx 127{,}69\ kW$$

Calculation of the area needed for the panels:

$$127.69\ kW \div 175\ W/m^2 \approx 729.6\ m^2$$

Calculation of the number of photovoltaic panels:

$$729.6\ m^2 \div 1.6\ m^2 \approx 456\ m^2/paneli$$

The investment cost of the farm in question will be approximately PLN 1 500 000 for the company. Included here are such costs as:

- materials – the purchase of photovoltaic panels, which can depend on their type, brand, efficiency, size and quality;
- installation – the assembly of the photovoltaic panels and staff time - connecting, etc;
- infrastructure – costs related to the construction of foundations for the panels, mounting platforms, fencing or an access road;

- regulations and legislation – permits, notifications, and costs associated with environmental and safety compliance;
- maintenance and service – regular maintenance, repair and possible upgrades to the photovoltaic system.

The time after which the investment would pay off was calculated on the basis of available data:

- investment outlay: 1 500 000 PLN,
- annual energy production: 850 590 kWh,
- energy sales price: 0,87 PLN/kWh,
- annual operating costs: PLN 556 328.76.

Calculation of annual revenues from energy production:

$$850\ 590\ kWh \times 0{,}87 \frac{zł}{kWh} = 740\ 013.30\ PLN$$

Calculation of the value of the annual savings resulting from the investment:

$$740\ 013.30\ PLN - 556\ 328.76\ PLN = 183\ 684.54\ PLN$$

Calculation of the payback period:

$$1\ 500\ 000\ PLN \div 183\ 684.54\ PLN \approx 8.17\ years$$

The return on investment is expected to be around eight years. Once this renewable energy source is established, the company will be able to produce its own electricity, which will reduce the dependence on traditional energy sources and thus reduce the electricity costs that the company currently has to pay. Importantly, the use of solar energy is linked to promoting sustainability and improving the energy balance. The use of this energy does not produce harmful substances or generate carbon dioxide emissions, which contributes to the reduction of greenhouse gas emissions and has a positive impact on the environment.

The CE at Grolder Sp. z o.o. would look considerably more efficient once all investments have been made (Figure 1). The plant will carry out these activities in accordance with its sustainability policy. After cultivating the fields and harvesting the crops, the company would feed the pigs with their own grain, then they would produce slurry, which would be poured onto the fields via a pipeline system. The slurry produced, combined with cereal residues or bio-waste, would be fed into a biogas plant, where biofuel or electricity would be generated and further circulated for the company's operations. The resulting substrate from the biogas plant would circulate through the company by means of a pipeline system to the fields instead of slurry, with additional benefits for the soil and the local ecosystem. Such manure would be distributed to the fields so that the crops sown could grow, and this provides an opportunity to feed it to the pigs. By generating energy, the photovoltaic panels could in turn generate electricity to serve the biogas plant or the pipeline system that would be powered by this energy.

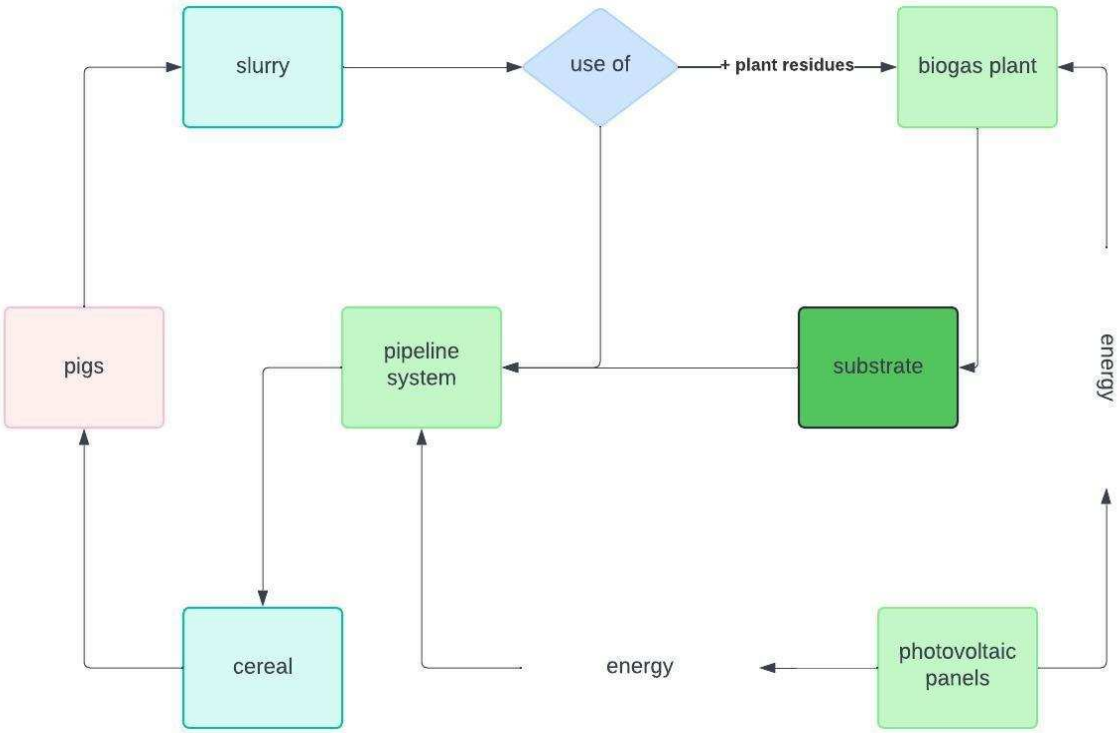

Figure 1 The CE concept on the example of Grolder Ltd.

5 Conclusion

Logistics plays a key role in the implementation of the circular economy concept in agricultural enterprises. The introduction of efficient logistics solutions in line with CE principles brings environmental, economic and social benefits, which is indispensable for sustainable development. Efficient management of logistics processes in agriculture allows for a significant reduction in the emission of harmful substances into the atmosphere.

At Grolder Sp. z o.o., the implementation of the CE could be achieved by investing in a pipeline system, photovoltaic panels and a biogas plant. The use of this pipeline system for transporting slurry or substrate from the biogas plant instead of traditional barrels reduces emissions and fuel consumption. In addition, optimising transport routes with advanced fleet management systems will lead to a reduction in fuel consumption and CO_2 emissions. In this way, logistics supports agricultural operations but also actively contributes to environmental protection. By investing in modern logistics technologies such as a biogas plant or photovoltaic panels, the energy efficiency of agricultural businesses can be significantly improved. The use of renewable energy sources in logistics processes, such as powering agricultural machinery with biomass fuels, offers the opportunity to reduce the company's dependence on fossil fuels, which can not only reduce the carbon footprint, but also lower operating costs, which is crucial for the competitiveness of agricultural businesses.

The application of the CE concept in agricultural enterprises influences the logistical processes there through better management of raw materials, time and costs. Agricultural enterprises that invest in a circular economy gain a competitive advantage in the market. This is because customers increasingly prefer products from sustainable sources. In addition, businesses that demonstrate environmentally sound practices are better perceived. Furthermore, the implementation of such solutions can lead to various environmental certifications, which further increases their attractiveness in the eyes of consumers. Logistics is thus becoming an integral part of the implementation of a circular economy in agricultural enterprises, and its role goes beyond traditional transport and storage functions to become a key tool to support sustainability, technological innovation and, above all, environmental protection. Agricultural enterprises implementing CE strategies are considered green, while at the same time such a company policy is profitable in the long term. Farms are more self-sufficient and waste is reduced, which every enterprise should reduce.

References

[1] BIEŃ, J., BIEŃ, B.: *Biogazownia rolnicza elementem programu gospodarki odpadami i wytwarzania zielonej energii w gminie*, Częstochowa, Wydawnictwo Politechniki Częstochowskiej, 2010. (Original in Polish)

[2] CHOPRA, S., MEINDL, P.: *Supply Chain Management: Strategy, Planning, and Operation*, London, Pearson Education Limited, 2018.

[3] CHANDRAPPA, R., BHUSAN DAS, D.: *Solid Waste Management: Principles and Practice*, Springer, 2012.

[4] DEGUNTHER, R.: *Solar Power Your Home For Dummies*, For Dummies, 2010.

[5] GAJDZIK, B.: Wprowadzenie do systemów logistycznych gospodarki odpadami w przedsiębiorstwach hutniczych, *Logistyka*, Vol. 2009, No. 5, 2009. (Original in Polish)

[6] GÓRAL, J., REMBIUSZ, W.: Produkcja w rolnictwie w kontekście ochrony środowiska, *Roczniki Naukowe Ekonomii Rolnictwa i Rozwoju Obszarów Wiejskich*, Vol. 2017, No. 1, 2017. (Original in Polish)

[7] KACPRZAK, M.: *Waste management logistics on the example of the Grolder Sp. z o. o. company*, Zielona Góra, Engineer's Thesis, 2024.

[8] KALICZYŃSKA, M.: Logistyka – cele i kierunki rozwoju, *Pomiary Automatyka Robotyka*, Vol. 10, 2009. (Original in Polish)

[9] KULCZYCKA, J.: *Gospodarka o obiegu zamkniętym w polityce i badaniach naukowych*, Kraków, IGSMiE PAN, 2019. (Original in Polish)

[10] KULCZYCKA, J., PĘDZIWIATR, E.: *Gospodarka o obiegu zamkniętym – definicje i ich interpretacje*, Kraków, IGSMiE PAN, 2019. (Original in Polish)

[11] JASKULSKI, D., JASKULSKA, I.: *Współczesne sposoby i systemy uprawy roli w teorii i praktyce rolniczej*, Poznań, Centrum Doradztwa Rolniczego w Brwinowie, 2016. (Original in Polish)

[12] JAWORSKI, T., GROCHOWSKA, S.: Circular Economy - the criteria for achieving and the prospect of implementation in Poland, *Archives of Waste Management and Environmental Protection*, Vol. 19, No. 4, 2017.

[13] MUSIAŁKIEWICZ, R., WALCZAK, D.: Rolnik indywidualny (mikro) przedsiębiorca czy rolnik? Analiza ekonomiczno-prawna, *Ekonomiczne Problemy Usług*, Vol. 2014, No. 111, 2014. (Original in Polish)

[14] NOWAK, A., KIJEK, T., KRUKOWSKI, A.: *Polskie rolnictwo wobec wyzwań współczesności*, Uniwersytet Przyrodniczy w Lublinie, Lublin, 2019. (Original in Polish)

[15] SKOWRONEK, C., SARJUSZ-WOLSKI, Z.: *Logistyka w przedsiębiorstwie*, Warszawa, PWE, 2012. (Original in Polish)

[16] STEVENSON, W.: *Operations Management*, McGraw Hill Higher Education, 2006.

[17] TWARÓG, J.: *Koszty logistyki przedsiębiorstw*, Poznań, Instytut Logistyki i Magazynowania, 2003. (Original in Polish)

[18] TYSZKA, J.: *Panele fotowoltaiczne*, Wieś Mazowiecka, Mazowiecki Ośrodek Doradztwa Rolniczego w Warszawie, No. 10, 2015. (Original in Polish)

[19] Ustawa z dnia 10 kwietnia 1997 r. Prawo energetyczne, art. 3, pkt. 20a, Dz. U. 2006, nr 89, poz. 625, z późn. zm. (Original in Polish)
[20] WALCZAK, J., GAJ, R., JADCZYSZYN, T.: *Ograniczenie zanieczyszczenia azotem pochodzenia rolniczego metodą poprawy jakości wód*, Warszawa, Wydawnictwo Fundacja na rzecz Rozwoju Polskiego Rolnictwa (FDPA), 2018. (Original in Polish)

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