Journal of Green Economy and Low-Carbon Development
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Innovative Approaches to Solid Waste Collection in Rural Areas: Advancing Circular Economy Practices through Sustainable Waste Management

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Received: 07-10-2024 **Revised:** 08-28-2024 **Accepted:** 09-13-2024

Citation: B. Novarlić and Ž. Stević, "Innovative approaches to solid waste collection in rural areas: Advancing circular economy practices through sustainable waste management," *J. Green Econ. Low-Carbon Dev.*, vol. 3, no. 3, pp. 187–194, 2024. https://doi.org/10.56578/jgelcd030304.

Abstract: Solid waste management in rural areas remains an underexplored domain, despite its growing significance in the context of environmental sustainability and the circular economy. Key challenges include inadequate municipal infrastructure, a shortage of waste collection containers, and the absence of suitable vehicle fleets capable of navigating narrow and steep rural pathways. Moreover, the lack of a strategic framework for waste management, the insufficient application of the 3R (Reduce, Reuse, Recycle) principles, and the absence of circular economy practices further exacerbate these issues. In rural areas, approximately 40% of the waste produced is organic and could be used as a resource for compost production, a valuable input for organic agricultural practices. Projections suggest that by 2027, biowaste will account for 8% of the total waste generated in rural communities. The transition to a circular economy offers significant potential for transforming waste management practices in these areas. Emphasis on innovative collection methods, such as localised and adaptive waste separation techniques, can facilitate this transition. The adoption of circular economy principles in waste management strategies is critical, not only for reducing environmental impact but also for promoting resource efficiency, enhancing soil fertility, and supporting sustainable local economies. Raising public awareness, engaging local communities, and introducing more effective waste management systems will be vital in overcoming existing barriers and ensuring the success of these initiatives.

Keywords: Comprehensive waste management; ISO 9001:2015; Circular economy; 3R; Compost; Raising public awareness; Local community; Real sector

1 Introduction

Bosnia and Herzegovina, continuously for decades, has been trying to find its connection with modern Europe and its innovative, as well as developmental policies in the field of environmental improvement. The main problem in the field of waste management in B&H lies in aligning policies and regulations, as the country has two entities and the Brčko District, each with different legal frameworks. It represents one of the most important obstacles in establishing a systemic approach to comprehensive waste management.

On the other hand, numerous recent studies conducted in Bosnia and Herzegovina have shown that there is a lack of public awareness regarding the extraction of useful secondary raw materials from waste [1], as opposed to simply filling regional and sanitary landfills without intermediate treatment [2]. Additionally, there is a lack of cooperation among citizens in terms of collective initiative - the local community is a place for a healthy life for all residents [3].

The focus of our research will be the local community – the city of Doboj, specifically rural areas, which for decades have been "exempt" from paying for waste disposal services. However, since January 1, 2024, all rural areas have been required to pay a fee to the utility company for waste collection and transportation services, instead of the previous practice of irresponsibly bringing waste to the city without charge, as well as the illegal (prohibited) burning of waste in open areas (arable/non-arable land, along rivers, near forests, etc.).

The expected results of this research, as well as other similar studies in this field, will focus on approaching and adopting the so-called EU "waste" package through a comprehensive set of laws aligned with the EU package. On the

other hand, the main aspiration is based on the principle of a unified political framework, which enables the transition to a circular economy with a particular emphasis on raising public awareness in rural areas about waste separation at the point of origin through the extraction of useful secondary raw materials and specific categories of waste. Earlier studies have highlighted the importance of campaigns in raising public awareness about natural phenomena [4] as well as waste management. No matter how much space we have for waste disposal, without intermediate treatment and the involvement of all stakeholders in the waste management chain, we will neither achieve the set goal nor preserve the health of the local population or the environment.

Special attention should be given to studying the optimal approach to rural areas in terms of comprehensive waste management as part of a unified strategy. On the other hand, achieving the aforementioned goal requires directing efforts toward EU foreign donors in order to create an optimal strategy for the management of non-hazardous municipal waste, as well as building the necessary municipal infrastructure and providing machinery in rural areas. Another very important goal is to recognize the natural resources that villages have, as well as the waste, particularly its increased amount that is generated in the spring and summer periods (food scraps from fruit and vegetables and similar waste), which is ideal for the production of natural fertilizer – organic compost. Let us seize the opportunity nature offers us today, as tomorrow it may be too late.

In this review paper, we will present a theoretical model for waste management in the rural areas of the city of Doboj, as part of the national strategy for comprehensive waste management, which can serve both the local community of the aforementioned area and as a pilot project for all other local communities in both entities and in the Brčko District. By reviewing the literature of relevant studies, we will highlight the role and significance of villages, both from the perspective of natural well-being and as an integral part of comprehensive waste management.

2 Literature Review

Comprehensive waste management represents a great challenge but also an opportunity to use all potentially useful materials from waste (secondary raw materials) in a new cycle of reproduction through the so-called circular economy. Bosnia and Herzegovina possesses great natural resources that provide it with a unique opportunity not only in tourism but also in the continuous maintenance of people's health, which includes organic food and a healthy life. However, B&H lacks a systemic approach to developing a unified legal framework that would bring it closer to the EU, particularly considering comprehensive waste management. This is primarily due to the unstable political environment, as well as the lack of a unified law at the level of both entities and the Brčko District.

On the other hand, Croatia, as an EU member, has enormous potential for accumulating financial resources for the construction of municipal infrastructure and technical support in waste management, which is particularly reflected in the co-financing or the complete construction of recycling yards [5], sanitary landfills, and enabling the implementation of a systemic approach to door-to-door waste collection, with previously separated waste at the household level.

A significant role in the separation of waste materials from total waste is played by dry waste components such as paper, cardboard, and plastic, which can be used in the production of waste-derived fuels [6]. Similarly, separately collected biowaste, through biological treatment under anaerobic conditions, generates electrical and thermal energy, with the final result being compost [7]. This compost or fertilizer is directly used in agricultural production, and given its structure and composition being of organic origin, it is indisputable that it is excellent for agricultural production, with the final output being organic food.

On the other hand, developed countries, such as Japan, face a shortage of usable space (in contrast to poorer countries) for disposing of waste that cannot be recycled or used in a way that creates new, usable value [8]. These countries design their comprehensive waste management concept based on the 3R principle (Reuse, Reduce, and Recycle) in pursuit of the so-called "zero waste" concept. Waste management represents a special link between nature and humans, between the natural world and any other state that attempts or makes efforts to disturb natural principles [9].

Research has shown that by 2050, the amount of waste produced worldwide will increase by 19% in developed countries, while, in low-income countries, this increase will be up to three times greater. Thus, a clear and precise strategy is needed in both observed areas to ensure that this wave of waste is properly managed in a timely manner, respecting the laws of nature and human health [10]. Therefore, the construction of municipal infrastructure and the procurement of modern machines for managing specific categories of waste will contribute to improving the aforementioned system.

Numerous studies have shown that utility companies cannot build an infrastructure system for waste management and technical support in a short period of time, due to both the lack of a trained workforce and the geographic location of villages and access roads [11]. On the other hand, improper waste disposal and lack of education on this issue in rural areas lead to environmental pollution [12], thus affecting human health. Therefore, increased education is needed, along with the establishment of a link between socio-demographic variables and the population.

Studies [13–15] have shown that, despite the global promotion of waste management and the establishment of

mechanisms that reduce the amount of useful waste from the total amount of waste, while protecting the environment and preserving natural resources, landfills and human health, there remains a significant lack of public awareness and a desire to leave future generations a safe and healthy place for living. Landfills as waste disposal sites are insufficiently "mined" in terms of useful raw materials (plastic and PET, cardboard and paper, glass bottles, wood and metal), which remain simply disposed of in landfills without being utilized through innovative machines for waste separation and with a lack of all stakeholders in the waste management chain. Interesting studies [16] conducted in transition countries, such as Bosnia and Herzegovina, have shown that rural areas are experiencing accelerated accumulation of solid waste, and its failure to be properly managed in a timely manner leads to the creation of potential illegal dumpsites, the spread of viruses, and a threat to public health in the observed area. The lack of a strategy for managing solid waste, inadequate machinery, low public awareness, and insufficient education contribute to soil pollution in the long term, as well as to the deterioration of food quality for human consumption and for livestock [17].

On the other hand, developed villages in China, unlike developing countries, have a larger population in the observed area and a rapid increase in solid waste. Research [18] has shown that in such areas, centralization of the waste management system is necessary, reducing working hours to five hours a day for the collection and transportation of solid waste, along with continuous financial satisfaction for workers, the renewal of waste disposal containers, and constant modernization of the vehicle fleet.

The local community can be the brain of the operation when it comes to managing solid waste, particularly by using innovative methods in solid waste management through mobile applications that calculate the temporary amount of solid waste and the method of its disposal, with the ultimate goal of preventing environmental pollution [19]. The developed world goes even a step further, using the interaction between humans and robots, where the user manages the interaction through a human reality interface via a mobile application – the user communicates with the waste management system through the application and signals locations where solid waste is being disposed of, actively participating in its management [20, 21].

On the other hand, research has shown that the concept of a circular economy provides a solution to the problem by creating new products from waste resources, which have economic value [22]. One of the specific goals is not only to manage secondary raw materials from total waste but also to manage solid waste, as well as waste generated at the household level, which is immediately sorted according to its category. The circular economy, based on the 3R principle, along with a chain in which all actors will be the strongest links, is the key to sustainable development [23].

Investing in eco-innovations in the field of the environment generates long-term benefits since waste is transformed into a highly important and valuable resource through the implementation of a circular system. Secondary resources in their pure form, which align with the new system of reproduction, are becoming increasingly scarce, while environmental pollution is on the rise, creating an imbalance between the observed activities [24]. Studies [25, 26] have shown that, in the context of the circular economy, there is no unified theory that addresses the significance and outlines all the possibilities for managing useful waste in relation to the total amount of waste.

From the perspective of rural areas, all households should strive to dispose of food waste by producing clean, organic compost intended for further agricultural production. Other studies highlight the significance of plastic bags in rural environments and the long-term reduction of their use, with the exception of recyclable and paper bags [27], all aimed at protecting the environment. This also includes the proper disposal of glass bottles due to their inability to decompose in the earth's crust, as well as the disposal of solid waste according to clear guidelines set by the local community. Circular economy should particularly be emphasized in developing countries, those striving to catch up with the "modern" and developed world, by improving recycling management policies, sanitary landfills, so-called waste banks, the 3R principle, and greater coordination at the urban-rural level [28].

For the concept of a circular economy to be applicable, it must first be clearly understood by the local community, equipped with the necessary knowledge, skills and capabilities for waste management, with a particular focus on household waste [29]. Local communities must apply the principle of converting waste into an economic asset, with the aim of maintaining ecosystem stability in the future [30]. An advanced local community is one that creates general satisfaction and well-being, both for its residents and for nature in a broader sense. On the other hand, adopting a clear circular economy model and ensuring its long-term sustainability also contributes to the economic prosperity of the local community. Villages are the essence of life and an integral part of a community, and they should receive more attention in the future, viewed through the lens of comprehensive waste management and emphasizing the sense of belonging to the community, just as is the case in urban areas.

3 The Role and Importance of Villages in Comprehensive Waste Management

The topic addressed in this paper is highly relevant and worthy of attention, especially considering that the city of Doboj, i.e., the authorized waste collection and transport company, has introduced a legal obligation as of January 1, 2024, requiring all villages to be included in the waste collection and transport service for a fee.

The previous practice in rural areas involved merely disposing of waste in "improvised" dumpsites near forests,

rivers and similar locations, instead of properly disposing of the waste at a registered municipal landfill. However, alongside this practice, there has unfortunately been an increasing trend of open-air waste burning, which not only harms human health but also further contaminates the soil, the very source of life.

Therefore, systemic action is needed in the field of comprehensive waste management, with a special emphasis on the strategic strengthening of rural areas. Raising public awareness in rural areas is the first and primary goal, not only of the city authorities but also of the utility company and all stakeholders in the waste management chain. Why do we refer to raising public awareness as the primary goal? Continuous education, through increased financial investment aimed at training all rural residents, is necessary to help them acquire new knowledge and develop new habits. Namely, waste (mixed, bulky and compostable) should be treated as a resource from which new value can be created, or even, in some cases, it can be used for the generation of thermal or electrical energy.

Continuous workshops in rural cooperatives on the role and importance of waste, its separation, and recycling should be at the top of the priority list. Accurate and comprehensive information, which will be provided to residents of rural areas on an ongoing basis, is the next crucial activity. Fostering a positive mindset, along with a constant emphasis on the practice of sustainable waste management in daily life, should be promoted, starting from the youngest age groups to retirees. In Figure 1. we will explain key steps in changing the behavior of residents in rural areas and which includes the four key elements of public awareness, knowledge, attitudes and behavior.

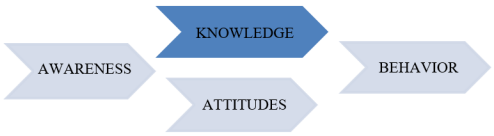

Figure 1. Key steps in changing the behavior of residents in rural areas

Awareness, as a primary factor – and we emphasize its importance once again – is crucial for informing the public about waste separation at the source (household or industrial activity, business, etc.) and recycling. Knowledge serves as the messenger of accurate and comprehensive information regarding waste management. Attitudes act as motivators of a positive mindset towards responsible and rational waste management and behavior as a factor that will encourage citizens to embrace new and innovative waste management practices and not resist changes.

For the previous activity to be realistic and feasible, it is necessary to take the following steps:

- After raising public awareness about the role and importance of waste, start immediately from the “zero” position and conduct discussions in a way that educators meet the participants at their level;

- Overcome the ”fear” of change and help target groups adapt to new practices (separate disposal of mixed versus secondary raw materials, as well as waste generated from food waste - compost), for the mutual benefit of both the utility company and the residents of the observed area;

- Use terminology that is appropriate for the listeners, starting from the beginning of the education and continuing throughout all future training. Given that we live in the 21st century and in the era of the Internet, it is necessary to run campaigns on comprehensive waste management through social media, but also through traditional methods: newspapers and radio. The distribution of promotional (educational) materials along with waste disposal equipment (120-liter municipal bins) will provide direct satisfaction to the interested parties, especially the residents of rural areas (waste will not be wasted and will be properly managed).

It is also essential to define the parameters for evaluating the success of the aforementioned campaigns and promotional activities, including factors such as media visibility, the impact of social media, and local community engagement. These can be assessed through various forms of advertising, such as advertisements, billboards, and other promotional channels.

The public awareness campaign is key to initiating change through the transition to a circular waste management system. This is supported by raising public awareness with collective efforts to maintain reasonable waste disposal, following the principle of “no surplus”, i.e., reasonable consumption and consumerism lead to better overall waste management. Only by working together can we have a significant impact on waste reduction and resource conservation.

3.1 Solid Waste Management Model: Opportunities and Challenges

The revitalization of waste management in the city of Doboj has begun on January 1, 2024, when the waste collection service and its transportation to a registered landfill from rural areas started. The coverage of rural areas is 49%, according to the data held by the utility company, which is authorized for this service. Therefore, 33 local communities are currently covered by this service, with the goal of including all 67 by 2029. The coverage of 49% is the result of the activities of the company Progres, which encouraged local communities to use this service in the past period. According to the Performance Audit Report of the Republic of Srpska [31], the total amount of

waste collected in 2020 was 400,000 tons, of which 40% was municipal waste, with a particular focus on garden and organic waste, and 40% was secondary raw materials (paper and cardboard, PET packaging, foil over 50 microns, etc.). The previous statement should be taken with caution, as around 30% of the population is not covered by this service, and in 90% of cases these are rural areas.

Therefore, as can be concluded from the paragraph above, rural areas represent both a challenge and an opportunity in comprehensive waste management, especially in all local communities, where this provision is legally defined, as is the case in the city of Doboj. The following illustration highlights the comprehensive waste management chain in rural areas that represent a current gap with the urban zone. The implementation of the comprehensive waste management system will be a significant challenge in the future.

Table 1. The state and perspectives of systemic waste management in rural areas with a specific emphasis on bulky waste

Activity	Current State	Desired State/Future Vision
State of municipal infrastructure	Lack of municipal infrastructure: - Specialized containers for mixed municipal waste, as opposed to recyclable materials; - Non-standardized existing containers for waste disposal (120 and 240 -liter bins, and 1,100 -liter and 5 m^3 containers) and the lack of defined locations for bins and containers for waste disposal; - A decades-old vehicle fleet with predominantly Euro 3 and Euro 4 engines (increasing fuel and lubricant costs year after year); - Lack of mapped transport routes for the collection of mixed and solid waste.	- Standardized containers for all residents (natural persons) and special containers for legal entities, with the ultimate goal of optimizing waste collection without unnecessary idling; - Procurement of bins for separating dry fractions (especially for dry secondary raw materials and in particular, future compost); - Procurement of vehicles with Euro 5 and Euro 6 engines (optimizing overall fuel and lubricant consumption and reducing maintenance costs); - Waste collection and transportation without idling, with optimization of the amounts of collected solid and mixed municipal waste.
3R (Reuse, Reduce and Recycle)	- Simple disposal of waste by ”inertia” and creation of illegal dumpsites.	- Systemic approach to waste collection (door-to-door); - Separation of useful raw materials from the total waste and their recycling; - Procurement of specialized bins for composting (creating organic fertilizer from food scraps).
Public awareness	- There is no awareness among residents that waste must be collected and handed over to the utility company, which will transport it to the landfill.	- Disposal of mixed municipal waste in specialized 120-liter bins as opposed to secondary raw materials and potential compost (the utility company collects secondary raw materials free of charge and creates a larger volume for the disposal of mixed municipal waste – Residents will be satisfied because they will have more space for the disposal of non-useful (mixed) waste free of charge.
Feasibility study for separate collection of biodegradable waste	- State at the initial “zero” point (there is no clear vision).	- Procurement of composters for rural areas if the justification of the set condition is confirmed and if there is a sufficient quantity of the specified waste; - Each household in the observed sample must have two composting bins (in the first phase for wet waste and, after maturation, for dry waste, which, after three months, turns into organic fertilizer – compost); - Each household should have two composting bins or a 380-liter wooden composter.
Bulky waste collection	- Open-air waste burning or; - Disposal of waste in forest areas or near streams and rivers, or on abandoned land.	- Defining a schedule for waste collection by the utility company (spring and fall cleaning of urban and rural areas); – free of charge up to a defined weight limit for the specified waste category; - Procurement of specialized utility vehicles, such as lifters and loaders, to facilitate the collection of bulky waste without workplace injuries and replace the current reliance on manual labor.

Activity	Current State	Desired State/Future Vision
Digital platform for waste movement	- Not implemented.	- Each resident and business owner will have their own password to access the system and will be able to view the benefits of waste they can dispose of free of charge and vice versa. As a regular payer during the year, they will be able to dispose of a certain amount of solid and bulky waste at the recycling yard in the city of Doboj (under construction) free of charge.

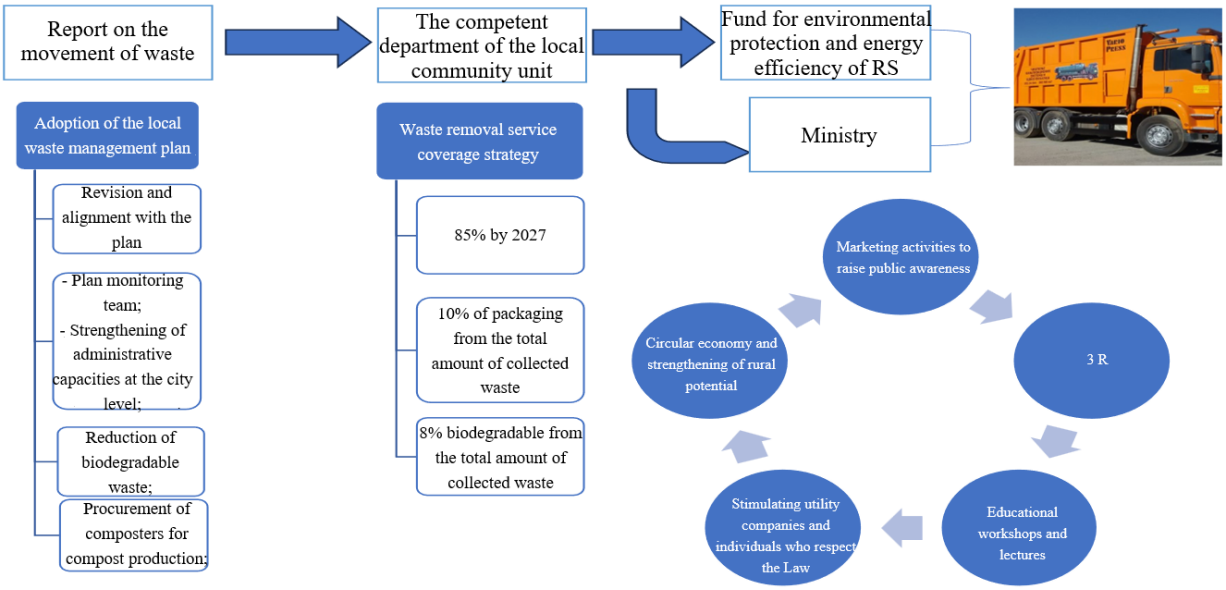

Figure 2. Proposed activities for strengthening the systemic waste management in rural areas

From Figure 2, it can be concluded that maximum involvement of all stakeholders in the comprehensive waste management chain is necessary if we want a successful implementation of the proposed model.

At the top of the pyramid is the relevant ministry in the Government of the Republic of Srpska and the Environmental Protection and Energy Efficiency Fund of the Republic of Srpska, followed by the local self-government unit, and, at the bottom of the pyramid, as one of the key actors, is Progres JSC Doboj and the population of the observed area (natural persons and legal entities). The most important resource, besides knowledge, is money, if we want the maximum implementation of the outlined strategy for rural areas as part of the comprehensive waste management.

In Table 1, we can see the current state and the desired – future state, in terms of the collection and transportation of non-hazardous municipal and bulky waste from rural areas. Therefore, in Table 1 we will present the status and perspectives of systemic waste management in rural areas with a special emphasis on bulky waste, which represents the current state in the aforementioned focus in relation to the future vision.

Therefore, the transition to a circular economy and strengthening existing capacities in the field of waste management in rural areas require both time and money. In addition to the primary goal, which is marketing activities aimed at raising public awareness, municipal infrastructure and cooperation between the local community and the observed area are particularly important, for mutual benefit. If one of the links in the chain fails completely or partially, the process of establishing a circular economy with the 3Rs will be postponed to some future period, which, we emphasize again, is not an optimal option in the long term. The village has nourished us and we will return to the village. Is there anything more beautiful than nature, clean air, and the village?

4 Conclusions

For decades, transition countries have been facing challenging circumstances that, in addition to the lack of financial satisfaction, also include a lack of public awareness, i.e., insufficient education of the population.

Raising public awareness in rural areas represents the first step in the systemic waste collection process, followed by defining the method of door-to-door waste collection. Bulky waste is a specific problem in terms of the total amount of waste generated daily. Additionally, we must consider population migration, especially during the summer and holiday periods, when the amount of waste produced increases. A special opportunity that must be utilized in rural areas is organic waste, which creates clean organic compost, intended for organic food production. The projection carried out by the Progres team of experts is that up to 8% of this type of waste will be achieved by 2027, which is an excellent projection from the perspective of the 3Rs as well as the circular economy, and also the reduction of the total costs of Progres.

Without the support of the state, the relevant ministry in the Government of the Republic of Srpska and the Environmental Protection and Energy Efficiency Fund of the Republic of Srpska, as well as the local community and the population of the observed area, the proposed system of comprehensive waste management and the transition to a circular economy is unsustainable. A systemic approach is required to build the missing municipal infrastructure in rural areas, including the procurement of trucks for the collection and transportation of non-hazardous municipal waste and secondary raw materials, newer models (hybrids or Euro 5 and Euro 6 engines), as well as co-financing the purchase of waste containers for the disposal of mixed municipal waste and secondary raw materials from waste, intended for the new production cycle, i.e., the creation of new value.

Are transition countries in a position and do they have the potential to implement a comprehensive waste management strategy and transition to a circular economy? Can the "distorted public awareness" regarding waste separation at the source and separation in accordance with legal regulations be changed? Can bulky waste be managed in compliance with the law and can public awareness be "strengthened" on this issue, with the ultimate goal being "0" amounts of bulky waste and the elimination of illegal dumpsites? These are just some of the questions that initiate the discussion for further similar research in the field addressed by this paper.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflict of interest.

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