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FERTILIZER PACKAGING COMPANIES OF PETROVIETNAM TOWARD CIRCULAR ECONOMY

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Summary

A circular economy is an economic system designed with the intention that maximum use is extracted from resources and minimum waste is generated for disposal... In the context of fertilizer packaging, manufacturers have been striving to produce green fertilizer bags which are recyclable, reusable and cost-efficient. When packages (both reusable and single-use) can no longer serve its function, the material should be circulated through recycling or composting. It is a matter of materials sciences (mono-material construction or material selection) and innovations in packaging formats (flexible packages, jumbo bags, sling bags, etc.) to make progress. Along with these, the sorting and collection infrastructure needs to be set up to keep products after use in a closed loop. As well, the economic attractiveness, incentives for stakeholders are essential to make the system work effectively.

Key words: Circular economy, recycle, re-use, compostable, plastic packages, fertilizer packaging.

1. Introduction

Seen as an auxiliary sector, the strong development of plastic packaging is driven by the development of other industries. Petrovietnam has two big fertilizer companies with a fast-growing rate recently, holding 50% share of the urea fertilizer market in the country. Therefore, Petrovietnam has expertise in making packages for agricultural products such as animal feed, chemicals, and fertilizers. However, the impacts of the plastic packaging industry on the environment are as significant as its growth rate.

The circular economy with the concept of minimizing negative externalities of products at the design stage is considered as one of the options for sustainable development of the packaging business. This paper focuses on fertilizer packaging in order to explore (i) What innovations of Petrovietnam fertilizer packaging over decades are; (ii) Whether circularity contributes to boosting the business performance; (iii) Which options for Petrovietnam fertilizer packaging be able to reach the circular economy.

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2. Theoretical framework

2.1. History of plastic packages

1933
Polyethylene was first synthesized.

1953
High-density polyethylene (HDPE) was invented, being light, moldable, and strong.

1965
Modern plastic bag was formulated by Swedish company Celloplast.

1982 and beyond
Plastic bags have become popular.

Figure 1. *The development of plastic packages [1].*

Since 1933 when polyethylene was discovered, it has become the most common type of plastics which has been increasingly used across the economy, serving as a key enabler for sectors as diverse as packaging, construction, transportation, health care and electronics. Plastics have brought massive profits to these industries thanks to their

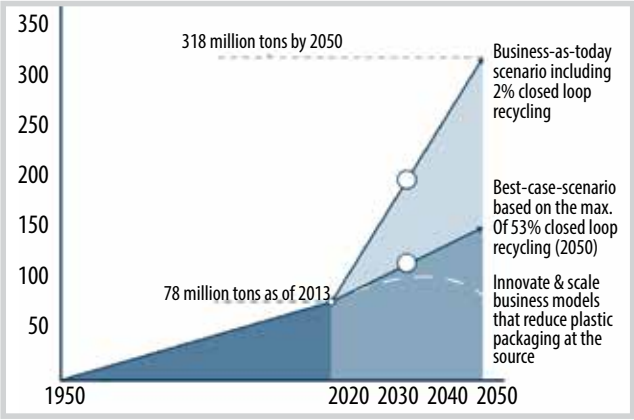

Figure 2. *Global plastic packaging production in the period 1950 - 2050 [2].*

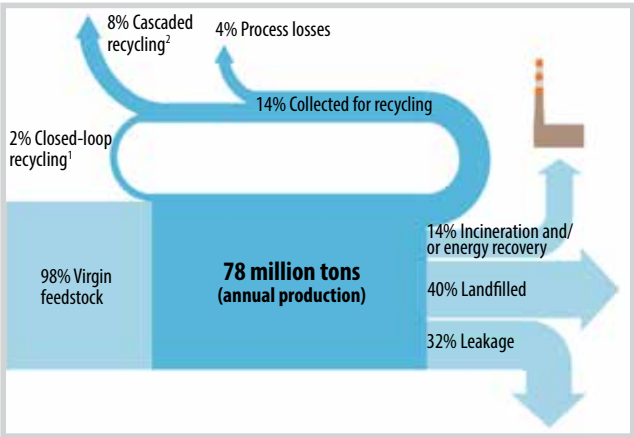

Figure 3. *Plastic packaging after use, in 2013 [2].*

combination of low cost, versatility, durability, and high strength-to-weight ratio [1].

Plastic packaging, the focus of this article, is and will remain the largest application that currently represents 26% of the total volume of plastics used. The success of plastic packaging is reflected in the exponential growth in their production over the last half century. Since 1964, plastics production had increased twenty-fold, reaching 78 million tons in 2013. Plastics production is expected to double again in 2030 in the best-case scenario based on the maximum of 53% closed loop recycling or quadruple by 2050 in the business-as-today scenario including 2% closed loop recycling [2].

As packaging materials, plastics are especially inexpensive, light weight and high performing. However, these generate adverse effects: degradation of natural systems as result of leakage, especially in the ocean[1], greenhouse gas emissions from production and after-use incineration, health impacts from substances of concern [2].

2.2. Fertilizer packaging

PP is one of the cheapest raw materials for the packaging industry. Although fertilizer products have different storage requirements, cost-effectiveness has led

Table 1. *Diferrent types of fertilizer packages*

 **Polyethylene (PE) bag** is flexible, durable and tear-resistant, high rate of waterproof/ moisture-proof; an anti-skid strip enables PE bags to stack steadier. However, it has weaker penetration resistance ability compared to PP woven bag [3]. Solutions: using the three-layered co-extrusion technology. This is a popular method recently applied in the production of PE bags by squeezing three layers of PE films into a stronger film so that it can stand to endure a higher level of penetration.	 **PP woven bag** is not only extra strength, durability but alsoallows air circulation through which gases produced by the fertilizer can be exhausted without worrying about the swell of the bag. In addition, the price of the bag is cheaper than other bags such as PE bags and flexible pouches. The woven allows air circulation but makes it vulnerable to the external environment too. The nature of the woven has also allowed moisture and contaminants to enter the bag. Solutions: there are alternative PP woven bags with coating and bags with liners. The coating has various kinds of choices including PE film coating, nylon coating, aluminum foil coating [3].
 **Kraft paper bag** is high elasticity and high tear resistance, vulnerable to any form of water. Water, moisture, or vapor can easily damage the packaging which leads to unnecessary leakage. There is a solution by adding an outer or inner layer of plastic film (BOPP) to the paper bag [3].	 **Flexible packaging[2]/flexible pouches** is the dominating packaging product that covers 80% of the total packaging production capacity. The cost of flexible pouches is relatively higher due to its production process. Additionally, the defects of flexible packages lie in their capacity. Flexible packaging is also called flexible pouches that have a capacity of only from 1 kg to 5 kg, which, to a certain degree, limited the usage in the industries that require larger capacity bags [3].

[1]*At least 8 million tons of plastics leak into the ocean each year which is equivalent to dumping the contents of one garbage truck into the ocean per minute [2].*

[2]*According to the Flexible Packaging Association, flexible packaging is any package or any part of a package whose shape can be readily changed, all kinds of bags, boxes, sets, and packages made of paper, aluminum foil, fiber, plastic film, and their composites are flexible packages. Flexible packaging can reduce overall material weight by 93% compared to rigid formats like glass bottles, saving valuable greenhouse gas production.*

to the widespread use of PP fertilizer bags. Recently, fertilizer packages have been considerably innovated with their own merits under different circumstances.

Fertilizer packages have changed over time, from PE bags, PP woven bags to kraft paper bag and flexible packaging, aiming to exclude the drawbacks to the environment and human health as shown in Table 1. Enhancing the circularity of plastic packaging while continuing to expand its functionality and reducing its cost could create a system that works - the circular economy.

2.3. Circular economy

In the current economy, we take materials from the earth, make products from them, and eventually throw them away as waste. The process is linear [4].

In a circular economy, we stop waste from being produced in the first place. A circular economy decouples economic activity from the consumption of finite resources. The circular economy is based on three principles [4]:

(i) Eliminate waste and pollution: we can treat waste as a design flaw. Specification for any design is that the materials re-enter the economy at the end of their use.

(ii) Circulate products and materials (at their highest value) by keeping materials in use, either as a product or as components or raw materials. This way, nothing becomes waste, and the intrinsic value of products and materials is retained. There are two fundamental cycles: the technical cycle and the biological cycle.

Figure 4. *The linear economy [4].*

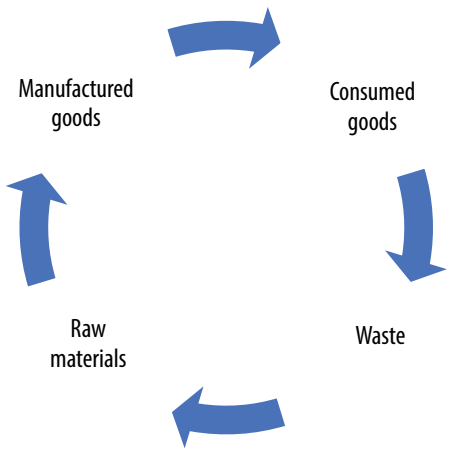

Figure 5. *The circular economy [4].*

In the technical cycle, products are reused, repaired, re-manufactured and recycled. In the biological cycle, materials are returned to the earth through processes like composting and anaerobic digestion.

(iii) Design is key: If designers thought about how their product could fit into the technical or biological cycles after use, that product could be made with that onward path in mind.

A circular economy - driven by design - is to consider waste and pollution as design flaws. Recycling might be called "end-of-pipe", dealing with a pipe of waste by energy intensive and supplemental virgin materials, while a circular economy's "upstream" solutions address potential problems right at the source - prevent waste from being create in the first place [4].

Two types of innovation are needed to achieve a circular economy: (i) upstream innovation (rethinking products and services at the design stage, for example: developing new materials, product designs or business models); (ii) downstream innovation (affecting a product or material after its first use, such as: developing new collection, sorting, and recycling technologies) [5].

3. Analysis of the cases

In December 2015, the European Commission adopted an EU Action Plan for a Circular Economy. It identified plastics as a key priority and committed itself to "prepare a strategy addressing the challenges posed by plastics throughout the value chain and taking into account their entire life cycle".

EU Regulations for Plastic Packaging includes key metrics: All plastics packaging must be reusable or recyclable in a cost-effective manner by 2030; recycling of 55% of plastics waste generated in Europe by 2030; greater use of innovative materials and alternative (i.e. non-fossil fuel) feed-stocks for plastic production where they are demonstrably more sustainable; a drastic decrease in the leakage of plastics into the environment; the consumption of single-use plastics will be declined, and the intentional use of micro-plastics will be restricted (banning of some products already in place); tax on plastics use; plastic packaging must be "single-piece" with no loose caps, fitments, etc, [6].

Figure 6. *Scholle IPN packaging solutions [6].*

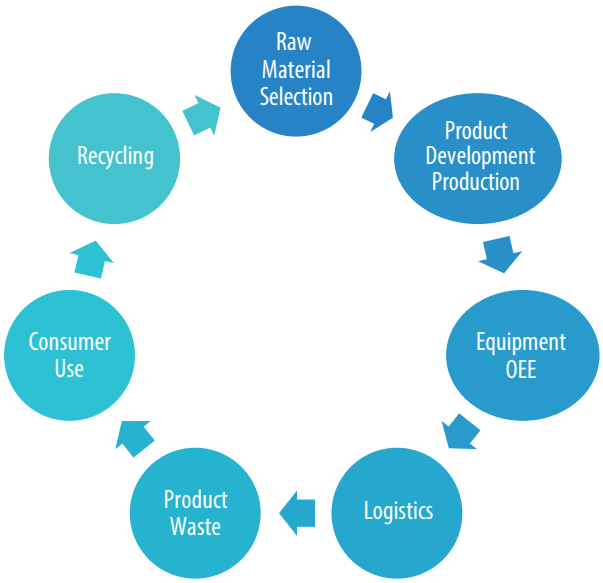

Figure 7. *Scholle IPN process [6].*

3.1. Scholle IPN

Scholle IPN is a leading packaging solution provider in the Americas and Europe. Products are packages for food, beverage to non-food such as: automotive fluids, coating, and agriculture chemicals (fertilizer, fungicide, herbicide, insecticide, plant growth regulator, rodenticide, seed treatment).

Scholle IPN approaches the circular economy with a wide range of principles.

Raw material selection: specifying base materials which are post-consumer recycled. Product development-production: Design for light footprint, recyclability, circularity with maximum performance. Equipment OEE: High-speed, efficient filling and sealing equipment runs on minimal inputs. Logistics: less weight, more product per pallet and truck, aseptic enables an ambient supply chain. Product waste: Extended shelf life with aseptic, 99.9% product evacuation, closed-loop dispensing options. Consumer use: Extended shelf life of opened products, simple ergonomics for all ages and abilities, re-closable fitments. Recycling: mono-material components engineered for mechanical/chemical recycling.

Scholle IPN practices recyclable film technology: extrude, laminate, and print flexible, barrier films; one-to nine-layer barrier films, as well as recyclable, mono-material structures; using solvent-free printing ink; eliminating solvents from the lamination process eliminates emissions; save raw materials by using fewer base materials (lightweight structures); eliminate lamination (films requiring no lamination use less energy and chemicals during production. The structures are also simpler, which aid in recyclability); and eliminate aluminum. Fitment innovation: injection mold and assemble fitments designed to provide an ergonomic interaction with products for all ages and abilities. Making sure closure components are disposable and recycled. Packaging equipment systems towards OEE: Engineered for maximum "up-time" to cut down time and materials wasted to troubleshoot production issues. Quick changeover: less waste in material, product, and labour with simple, fast changeover. Low maintenance requirements: simple maintenance regimens and easy to replace modules reduce downtime and travel required to service equipment in the field. Lifespan: Engineered sturdy materials that last for years when well-maintenance. Product flexibility: a single machine design could create several sizes and shape packages. Energy consumption: Designed to pull as little electricity, air and waste as possible during runs [6].

Scholle IPN with innovation and technical capabilities has enabled a significant reduction in the use of fossil materials and related CO_2 footprint along the whole process (from raw material selection to product development-production, logistics, consumer-use and recycling).

3.2. Petrovietnam packaging companies

In Vietnam Law on Environmental Protection 2020 taking effect on January 01, 2022, Article 54 Responsibility of Producers and Importers for Recycling requires: 1. Producers and importers of recyclable products and packages must recycle

them according to the mandatory recycling rate and specifications, except for products and packages exported/temporarily imported or produced/imported for research, learning or testing purposes. 2. The producers and importers specified are entitled to recycle products and packages adopting one of the following methods: a) Organize recycling of products and packages; b) Make a financial contribution to the Vietnam Environment Protection Fund to support recycling of products and packages [7].

Petrovietnam Packaging Joint Stock Company (PPC) was established in June 2010, well-equipped with European modern technology. Products are mostly for the domestic market: 85% for PetroVietnam Camau Fertilizer Joint Stock company (PVCFC), 15% for the Southwest region of Vietnam. The overseas markets are neighboring countries such as Cambodia, Laos, India, and Bangladesh [8].

Products:

- Laminated bag (PP woven fabric + lamination + Flexo printing[3]): Woven fabric ensures the strength while lamination is responsible for water resistance and improves physical-mechanical properties of the products.

- PP woven bag: Based on PP woven texture with none-laminated or laminated with 1/2 sides to produce species of high-quality bags, sealed, load bearing, model advertisement and especially woven PP friendly with the environment. Flexible-printing. Products have further internal PEHD, PELD bags.

- BOPP bag: PP woven bags + laminated glue + OPP film (gravure printing). Woven fabric ensures the strength while laminated glue is responsible for sticking the woven fabric and OPP film together; the OPP film used for gravure printing creates water resistance and improves physical-mechanical properties of the products.

Figure 8. *Domestic and export share in 2004 - 2023 [9].*

Figure 9. *Samples of PP woven bag (a), sling bag (b), and jumbo bags (c).*

Dam Phu My Packaging Joint Stock Company (DPMP) was founded in 2004. During 10 years up to 2013, it only produced for the local market (Petrovietnam Fertilizers and Chemicals Corporation – PVFCCo) Since 2014 PVFCCo Packaging has stared exporting to EU (Italia, England), USA, Korea, Thailand, Japan, Singapore, and Malaysia. During 2015 - 2017, it had 70% of products for domestic and 30% for export. In 2022 - 2023, the domestic use was around 40 - 50% and the rest was for exportation (Figure 8).

Products: PP woven bags (with PP lamination, flexo printing, BOPP woven); two loops big bag; garden bags; PP woven fabric; FIBC, big bag, jumbo bag (FIBC circular bottom, anti-bulge FIBC bag, baffle FIBC, circular jumbo bag, 4 panels jumbo bag, anti-bulging bags, FIBC U panel, etc.).

In 2017, DPMP began promoting jumbo bags[4] and small pouches for home gardens. Recently, sling bags[5] have also been introduced [9] (Figure 9).

Petrovietnam packages over decades have been refined to meet the demands of customers and national legal requirements. As being recognized as well-certified factories, they are successful in exporting bags to the U.S, Canada, Australia, New Zealand, Southeast Asia, and the EU.

As can be seen in Table 2, raw material and sourcing, recycling and enviromental pollution treatment have a high ratio (more than 80%) of by-products recycled in both factories together with various activities of recycling

[3]Flexo Printing/Flexography is a modern high-speed printing process suitable for most packaging and label applications. It allows for fast, cost-efficient, high-quality label printing for a variety of mass-produced goods.
[4] Jumbo bag (FIBC - Flexible Intermediate Bulk Container) (big bag, bulk bag) is a large size packaging made from woven polypropylene (PP).
[5] Sling bags: Thin, light, super durable, can withstand loads from 500 kg to more than two tons of goods. Low cost, can be easily folded and reused many times, saving costs. Loading, unloading, transporting goods safely and quickly. Goods can be stacked on top of each other, saving warehouse space and container. Thus, this kind of bags can store or transport more goods. It has a long shelf life, is recyclable, environmentally friendly. Sling bags of PVFCCo Packaging: Material: 100% virgin PP. Capacity: 500 - 2,000 kg. Denier: 1,400 - 1,600D/ Fabric weight: 170 - 200g/m^2. Density: 12x12-14x14. Base cloth: PP + laminated/no laminated, anti UV/no UV protection. Safety factor: SF3.1, 5.1, 6.1.

water, material surplus and solid waste originated from PP, PE.

4. Discussion

Figure 3 shows that in 2013 just 14% of after-use plastic packages were captured in the world. Even in the United States and Europe with advanced collection systems, 170.000 tons of plastics leak into the ocean each year [2]. According to the World Bank, Vietnam is among the top four generators of plastic waste, approximately 280.000 tons per year [10].

In both cases of Scholle IPN and Petrovietnam packaging companies, the amount of after-use packages has not been accounted. There is a great potential to redesign materials, packaging formats from the outset for fertilizer packages to be reused, recycled or compostable and hence reducing leakage proportionally.

- Re-use built on redesigning packaging formats

Reusable packages would save single-use ones from waste streams. Jumbo bags, pouches, and sling bags have a sufficiently high material value to make reuse business models profitable. They are often used 20 to 100 times depending on the application [2] and the vast majority are recycled afterwards, with the redesigned and innovative bags - mono structure. When packaging (both reusable and single use) can no longer serve its function, the material should be circulated through recycling or composting.

- Recycling, which means creating value after the initial use, mainly depends on redesigning materials or choices of materials.

Fertilizer packages require chemical resistance, water resistance, durability and lightweight. These are often combined with properties of materials. Multi-material packaging can often offer enhanced performance and resulting functional benefits, such as providing oxygen and moisture barriers at reduced weight and costs. As being made from multiple materials, fertilizer packages might be technically unrecyclable. For some applications, technologies exist that, in theory, could capture part of the material value through downcycling, i.e., the process of converting materials into new materials of lesser quality, economic value and/or reduced functionality. For example, compatibilizers are chemical substances that can allow some multi-material packaging to be downcycled into blended materials. Still, such technologies lead to significant loss of material value in the recycling process and likely add just one extra use-cycle rather than creating a truly positive, virtuous material cycle[6].

In the case of Scholle IPN, flexible packaging focuses on source reduction and simple, mono-material construction (high-barrier mono-material films). Bag-in-box and pouch packaging with mono-material films are easier to recycle and require fewer materials to produce.

- Making plastic bags compostable, means that an item with specific materials can break down into carbon dioxide, water and biomass within a specific time frame

Table 2. *Related indicators of PPC and DPMP*

	PPC	DPMP
Raw materials and sourcing	The materials mainly come from Binh Son Refining & Petrochemical Joint Stock Company (BSR). The rest is imported from Taiwan, Korea, Thailand.	90% of materials (Polypropylene) are imported.
Energy use	Using electricity, diesel oil. The quota for electricity used is 01 kWh per 1 kg of products;	Total electricity consumed is 620.000 kWh per year.
Recycling	More than 80% of by-products are reused, recycled.	The company produces 7.000 tons of PP annually. The quantity of by-products accounts for 7%, of which more than 80% is reused, recycled. Surplus of ink, paper is collected, reused/recycled. Solid waste originated from PP, PE is recycled.
Water withdrawal	Water is taken from two sources: water supply factory and groundwater.	Water is circulated for manufacturing.
Environmental pollution treatment	The systems of environmental pollution treatment meet the legal requirements of the government.	Solvent, containers of ink are transferred to the manufacturers. Industrial wastewater is treated before discharging. Hazardous wastewater (small amounts) and hazardous waste (about 200 kg/month) is collected and treated by third parties.

[6] *There are two levels of recycling: (i) Closed-loop recycling: recycling of plastics into the same or similar-quality applications. (ii) Cascaded recycling: recycling of plastics into other, lower-value applications [11].*

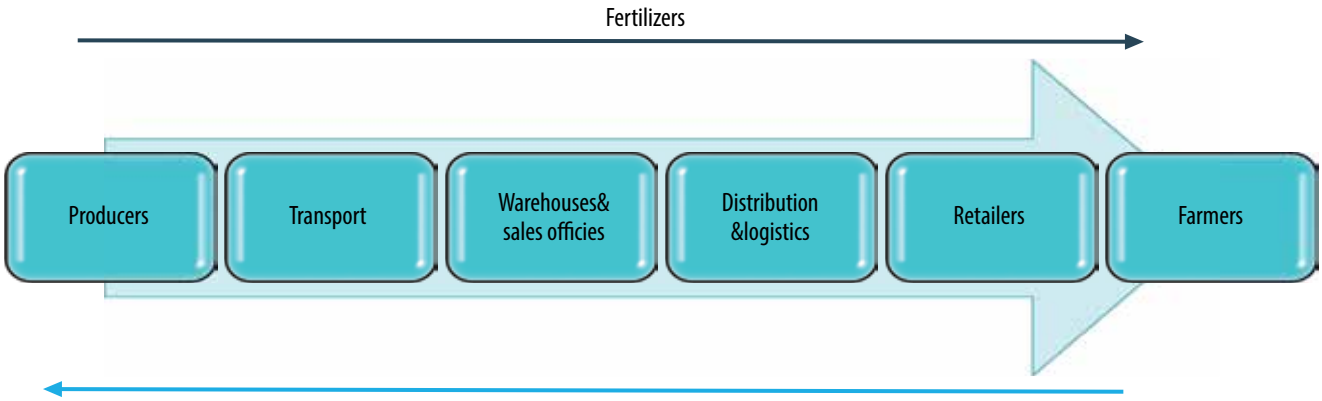

Figure 10. *The distribustion of fertilizers and the collection of used bags [11].*

Figure 11. *The collection infrastructure [5].*

and under specific, controlled conditions. Industrially compostable and home compostable are subsets of the term as packages still need to be collected and composted in well-managed facilities [11].

- It needs the design in not only materials, packaging formats but also sorting and collection infrastructure. In the case of fertilizer packages, those consist of two segments: (i) from business to business (B2B) (packaging companies to fertilizer companies to wholesalers/ agencies), (ii) from business to consumers (B2C) (retailers, shops to farmers) [2].

The collection infrastructure might be based on the existing product distribution systems: from producers to distributors, wholesalers, agencies to retailers, stores since the relationship formed to maintain a steady inventory flow. Now interconnected operators have responsibilities to manage a shared set of standardized, reusable packages [5]. The most important thing is to incentivize the return of packaging by developing the right deposit and reward mechanism for end-users (farmers) and other stakeholders in the chain.

Petrovietnam fertilizers have been distributed through more than 100 wholesalers/agencies, about 3.000 retailers/stores of PVFCCo and more than 53 wholesalers, and thousands of stores of PVCFC all over the country. These agencies and stores could be the drop-off points of fertilizer bags after use, and warehouses/wholesalers could be the collecting/sorting points to send used bags to the packaging companies.

- Besides environmental advantages, circular activities generate both economic benefits and costs. The costs are estimated to comprise investment in redesigning, related technologies (separation technology, reprocessing technology, etc.) and new materials (renewably sourced and decompostable plastics) plus expenses to remain the collecting scheme, etc. On the other hand, benefits of recycling, reuse might be quantified in regard to keeping materials in the system, creating economic values by increasing its reuse/recycling rates, decreasing budget for materials (for example, in PPC company, expenses of polypropylene are more than 70% of operating costs). Moreover, in the context of Vietnam Law on Environmental Protection as mentioned above, producers are entitled to either a) Organize recycling of products and packages; or b) Make a financial contribution to the Vietnam Environment Protection Fund. Once the companies approach circular activities, they would satisfy the legal requirements in the former way instead of the latter.

5. Conclusion

Two Petrovietnam fertilizer packaging companies have already developed products to be recyclable, re-usable, eco-friendly as well as meet international standards in recent years. In fact, achieving circulatory business would require joint efforts, not only designing better packaging (rethinking materials, packaging formats), but also increasing recycling/reuse rates (enhancing technologies), and introducing appropriate models for after-use collection/reprocessing infrastructure. Only when all of three axes come together, we can leverage the dematerialization process, reducing the need for raw feedstock and minimizing plastic waste. Particularly, the collection system could be integrated into the product distribution network: from producers to distributors, wholesalers, agencies to retailers together with the right deposit and reward for related stakeholders as economic attractiveness of returning used bags. In terms of cost-benefit analysis, environmental benefits and legal compliance would be determined in values in comparison with investment in redesigning, innovation, technologies and conducting the collection system for the packaging business to be sustainable.

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